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Fouad Abd-El-Khalick Ryan Summers

Development and Validation of a Rubric to Qualify and Quantify Responses to the VNOS Questionnaire

This study developed and validated a rubric to qualify and quantify Views of Nature of Science Questionnaire (VNOS) responses: The "VNOS Analysis and Scoring Rubric" (VAScoR). The rubric aims to reduce qualitative inferencing and standardize quantitative score assignment to substantially lessen the burden of, and variance in, VNOS analyses and scoring; improve validity and meaningfulness for crossstudy comparisons; and enable statistical analyses. We adopted a consensus NOS framework with core and related elements across 10 aspects. Data included 185 questionnaires from preservice secondary science teachers. One author's analyses of 86 questionnaires were used to examine VAScoR's content validity and intra-rater reliability. Inter-rater reliability was examined through four authors' analyses of a random, overlapping set of 18 questionnaires. Robust intra-rater and inter-rater reliabilities were indicated by a Cronbach's alpha of .81 and Cohen's kappa of .71, respectively. Inter-rater reliability was further evidenced by moderate to strong consistency among four raters with an overall Pearson's correlation coefficient of .82, and values ranging from .77 to .89 for six possible rater pairings. Finally, exploratory factor analysis supported a multi-dimensional, four-factor structure for ratings and scores, which was consistent with the VAScoR's theoretical framework and pairings of core and related NOS aspects and elements.

Mariyam Pentho Abdulhadi Peter A. Okebukola

Will CTCA Help Students' Understanding of Difficult Concepts In Computer Studies?

This study was in two phases (Survey and Experimental). The survey phase involved the researcher interrogating the students on topics perceived as difficult which has led to poor academic achievement in Computer studies. Among which Spreadsheet was mentioned, over the years various teaching methods have been deployed by teachers to teach spreadsheet and other perceived difficult topics, yet the result has not been encouraging as students tend to perform woefully in it. This study adopted the mixed-methods design to determine the efficacy of the Culturo-Techno Contextual Approach (CTCA) in breaking difficulties related to the study of Spreadsheet. A total of 65 junior high school students participated in the study. The experimental group (N=30) were taught using CTCA while the control group (N=35) were taught using lecture method. Spreadsheet Achievement Test was used to collect data. Ancova procedure was applied on the data with pretest scores inserted as the covariate. The results showed that the experimental group significantly outperformed the control group [F (1,60) = 41.89; p<0.05] which showed the potential of CTCA in improving students' performance. Within the limitations of the study, the exploratory use of CTCA for teaching computer studies in Nigerian school system and other recommendations were given.

Brian Abramowitz Minyoung Lee

A Bibliometric Analysis of Trends and Issues in Educational AI

The study examined the trends and issues in the burgeoning field of Artificial Intelligence (AI) in education through a bibliometric analysis. The International Journal of AI in Education (IJAIE) served as the dataset to inform researchers as the IJAIE is the flagship journal in the field. This study disseminates the most published AI in education keywords and the respective popularity of those keywords. In order to fill in gaps in AI research and better inform stakeholders, it is important to strengthening researchers' understanding of the research that has been addressed and where additional AI research needs lie.

Brian Abramowitz Pavlo D. Antonenko

Exploring Teachers' Conceptions of Artificial Intelligence in K-12 Science Education

This study explored the conceptions of rural elementary and middle school science teachers regarding artificial intelligence (AI) and the importance of AI in K-12 science education. Conceptual change theory informed the design of the study. Our findings show that teachers initially had a substantial number of misconceptions regarding AI (e.g., AI is new) and their conceptions significantly evolved as a result of a 2-month in-service learning experience. This study demonstrates that AI doesn't have to remain an ambiguous and ill-understood concept for educators and that if more teachers and children are going to use AI in the classroom, it is important to leverage teachers' conceptions of AI to integrate AI more meaningfully in their instructional practice.

Adrian L Adams Lauren A Barth-Cohen

Investigating Student Response to Anomalous Data When Analyzing and Interpreting Data

Recent reforms in K-12 and undergraduate science education have exposed students to more researchlike scenarios such as inquiry-based learning and reformed undergraduate labs. These reformed learning spaces often engage students in scientific practices like Planning and Carrying Out Investigations and Analyzing and Interpreting Data. Other scientific practices like modeling and argumentation have been amply researched. However, while sensemaking with their data, scientists often engage in data cleaning, the process of identifying and mitigating the effects of anomalous data. Data cleaning lacks a significant body of literature, even though students engage in this action in inquiry-based settings. We utilized think-aloud interviews and observational data of students in an undergraduate inquiry-based physics lab course to explore how students engage in data cleaning. Interviews and observation data were coded to capture students' process of engaging in data cleaning. Students in the lab spent less time discussing if an anomaly should or should not be deleted and seemed particularly focused on making data fit expectations when compared to interviewed students. This research highlights that students are capable of reasoning about handling anomalous data, but they may need more support in the lab to think critically about their data.

Johannes Addido

Addressing Pre-service Teachers' Misconceptions and Promoting Conceptual Understanding through the Conceptual Change Model.

This research study was conducted to investigate the efficacy of the Conceptual Change Model (CCM) in addressing pre-service elementary teachers' misconceptions and promoting conceptual understanding of forces and motion. A total of 34 pre-service elementary school teachers enrolled in the elementary physical sciences course participated in the study which was based on a 3-week course module on the topic of forces and motion. The data collection instruments used were open-ended pre and post-questionnaires about misconceptions on forces and motion, and students' journal submissions. The results showed that 30 participants showed full conceptual understanding, 4 showed partial conceptual understanding and none of the participants exhibited no conceptual understanding in their journal entry write-ups on forces and motion. The data showed that most participants provided more "scientifically accurate" responses in their post-lesson questionnaire compared to their pre-lesson responses. Overall, the findings made a positive case for the effectiveness of CCM as a pedagogical model in the promotion of conceptual understanding and minimization of misconceptions concerning the topic of forces and motion. This study is relevant in the brother sphere of promoting scientific literacy and the minimization of misconceptions about science topics. (Keywords: Science Education, Conceptual Change Model, Conceptual Understanding, Misconceptions)

Israel O. Adebayo Peter A. Okebukola

Examining the Relative Effectiveness of CTCA in Improving Secondary School Students' Achievement in Genetics

The study examined the effectiveness of a relatively new teaching method —The Culturo-Techno-Contextual Approach (CTCA) —in improving students' achievement in biology with specific focus on genetics. It was conducted in two phases. The first phase adopted the Difficult Concepts in Biology Questionnaire (DCBQ) for secondary school biology students randomly selected from both public and private schools in Nigeria and Ghana. Data obtained revealed variation and evolution as the most difficult topic in biology, closely followed by genetics. The second phase adopted the mixed methods (quasi-experimental and interview) design. A total of 62 students comprising 32 students taught using CTCA and 30 students taught using the conventional method made up the sample. Genetics Achievement Test (GAT) was used to collect data for this phase. ANCOVA was used to test for significant difference between the two groups at 0.05 level of significance. The results revealed a statistically significant difference in the mean achievement scores of students taught using CTCA and those taught conventionally, [x (experimental) = 24.59, x (control) = 17.07; F(1, 59)=25.99; p<0.05]. Within the scope and limitations of the study, it was tentatively recommended that CTCA should be adopted by biology teachers in teaching genetics in secondary schools.

Ibukunolu A. Ademola Peter A. Okebukola

Improving the Achievement and Problem-solving Skills of Students: How Effective is CTCA in Nuclear Chemistry?

This study was conducted in two phases, the first phase was survey of difficult concepts, while the second phase was an experimental study which employed an explanatory sequential mixed methods research approach involving collection of quantitative and qualitative data. The study had both experimental and control groups with a sample size of 102 senior secondary 2 (equivalent of 11th grade)

students. The experimental group had 53 students (22 male and 31 female) while the control group had 49 students (19 male and 30 female). One of the focus of this study is to find if there will be a statistically significant difference in academic achievement and problem-solving skills of chemistry students taught nuclear chemistry using CTCA and lecture method. Problem-solving skills [F (1,98) = 1.24; p = 0.27] failed to attain statistical significance. Statistical significance difference was found for achievement [F (1,98) = 9.28; p = 0.00]. This significance is in favour of CTCA. This study was able to make learning of science easy for the student through the use CTCA which is a student-centered method of teaching and learning. The study recommends that, the use of CTCA should be explored in other subjects in order to test its effectiveness.

Michael Adelani Adewusi

Learning Analytics in a Designed Learning Platform During the Covid-19 Pandemic

During the COVID-19 lockdown, this study was conducted using a machine learning analytics tool in a virtual learning environment. The goal of this was to train data gathered from students' online interactions with the platform. It is not to make predictions on the students, but rather to learn from the data, what the learners' interactions were in order to improve the platform for future course delivery, particularly assessment questions or exams. A Moodle Plugin Analytics Tool was used on a computer science education course with a total of 93 students for a semester. Findings show that several questions that were taught to be easy to answer were not. Although questions are designed to assess student's ability or knowledge in a specific area. Can one be certain that it is what is being measured? The learning analytics tool model analyzed the data using Regression Statistics to give student involvement with the questions in the virtual environment. It is suggested that as science teachers, we advocate the use of an analytical tool to evaluate online students in order to better comprehend their hidden insights. This strategy is better off from the use of surveys to assess their academic performance.

Deborah Oluwatosin Agbanimu Peter A. Okebukola

Flowchart and Algorithm as Difficult Concepts in Computer Studies: Can CTCA Come to the Rescue?

The focus of this study was to find out the reasons why students find algorithm and flowchart which has emerged as the most difficult concepts from the new computer studies curriculum in Nigerian secondary school and to determine the potency of the culturo-techno-contextual approach in the achievement of students taught flowchart and algorithm. This research employed a survey and quasi-experimental design. The study involved students from two public junior secondary schools three (grade 9) in Lagos State, Nigeria. The study had two groups which are control (51 boys, 44 girls) and the experimental (48 boys, 55 girls) groups, the instrument used was the achievement test (flowchart and algorithm achievement test) with a reliability value of .74, and interviews were conducted to gather data for the qualitative aspect of the study. Data gathered were analyzed using ANCOVA which was applied to the posttest scores of achievement of students taught flowchart and algorithm using CTCA and lecture method in favour of the experimental group (mean score for experimental =18.24; control=7.87; F (1, 193) =1119.86; p<.05]. Implications for the study were highlighted.

Rahmi Q. Aini Minsu Ha

Challenge in Reasoning about Evolution Acceptance for Muslim Students: The Mechanism of Motivated Reasoning

This study aimed to investigate the phenomenon of motivated reasoning in Muslim students and understand the culture and beliefs that contribute to the emergence of reasoning in evolution acceptance. A qualitative study using constant comparison analysis method was used in which 14 Indonesian science students participated. To understand how motivated reasoning occurs, two in-depth interviews with similar questions regarding evolution were conducted with each student with an average 10 days interval. It suggests that the phenomenon of motivated reasoning appears in the context of science learning whereby it is linked to their behaviors, strategies, and arguments when facing science-related information. Additionally, this study found that belief that attached in emotion influences students' reasoning and can demonstrated various biases and self-constructed misconceptions in their alternative explanations. To attempt reducing cognitive dissonance, the participants deliberate about scientific evidence and religious explanations about human evolution.

Zeynep Gonca Akdemir Muhsin Menekse

Exploring Student- and Teacher-Level Characteristics on Middle School Students' Engagement in Life Science Classes

This study examined the student- and teacher-level variability of middle school students' engagement through explicit integration of Life STEM instruction. It was hypothesized that having a science teaching license and gualification predict students' engagement in the dimensions of behavioral, emotional, cognitive, and social engagement, besides the student-level differences (i.e., gender, ethnicity, grade level). Data from 3,471 middle school students from the 6th, 7th, and 8th grades were analyzed. The nested structure of the dataset was analyzed through Hierarchical Linear Modelling in which studentlevel variables and teacher-level variables were independent, the dimensions of behavioral, emotional, cognitive, and social engagement change (post- minus pre-engagement survey scores) were stand-alone dependent variables in the hypothetical model. The preliminary results suggested that students' data significantly nested in classes only for the dependent variables of behavioral and emotional engagement change. However, all dependent variables significantly varied by teacher groups. Although most of the predictors were non-significant, variation sizes can explain that some variables were sizably related therefore collectively explained some of the models. Only for the emotional engagement change, being in 7th grade significantly explained the model, suggesting that the characteristics of some teachers taught in that grade should be closely examined in further studies. Keywords: student engagement, integrated STEM education, Life Sciences.

Valarie L. Akerson Judith S Lederman

The Unnatural Nature of Science without Norm Lederman: Honoring the Legacy of Dr. Norman Lederman

In this special memorial symposium, we will reflect upon and share insights and impacts of Dr. Norman Lederman on the field of science education, and particularly on Strand 13 for NARST. The session will be

open to audience members to share memories of Norm. Come and join your colleagues in honoring the legacy of Norman Lederman.

Selin Akgun

PBL Adaptation Principles to Support Equitable Science Instruction

Adaptation design principles that teachers use for enhancing student learning How can teacher professional learning be designed to promote teacher agency and responsive teaching? The goals for professional learning are multifaceted due to complex demands placed on teachers. While enacting curriculum, a teacher must be equipped to engage students productively. They must improvise teaching to support science practices and build on student experiences and current understanding, create equitable and culturally relevant contexts, and support social and emotional learning. This team of researchers from three universities presents a set of disparate but consequential design principles centered on supporting teachers to adapt curriculum according to context, focused on different teachers and grade levels, but all enacting Project-based Learning. An adaptation design principle is an actionable, evidence-based claim that teachers employ to navigate adaptations so teaching sustains the deeply rooted foundations of productive and responsive science teaching. Paper 1 explains the process for using adaptation design principles to frame Professional Learning. Paper 2 describes design principles for creating equity-centered environments, paper 3 is centered on the design principles that support engagement in developing, using and presenting models, paper 4 shows how adaptation design principles can be used in Professional Learning to leverage adaptations based on culturally responsive teaching.

Selin Akgun I-Chien Chen

Using ML-PBL Teaching Practices to Support Student Sensemaking and Social-Emotional Learning in Elementary Science Classrooms

There is a growing need to identify teaching practices that support students' scientific sensemaking, and social-emotional learning (SEL). Multiple Literacies in Project-Based Learning (ML-PBL) is an elementary curriculum system that promotes students' science learning and SEL experiences by leveraging sensemaking discussions and social integration of students in collaborative learning space. This study investigates the role of ML-PBL teachers' support on students' sensemaking and how their practices impact students' SEL experiences in science classrooms. Using classroom observation data of 36 teachers and SEL survey from 765 students, we leverage latent profile analysis (LPA) and multilevel model to measure the patterns of teachers' use of core ML-PBL practices and assess the relationship between their level of support for student science sensemaking and SEL. Results of teacher observation indicate three patterns of teacher support in supporting students' sensemaking across units: stable-supporters, low-starter and regressors. The quantitative analysis indicates an improvement of students' self-reflection and collaboration skills in classrooms where teachers' support in student sensemaking. This study suggests that teachers' support in student sensemaking.

leads to the enhancement of their social and emotional learning, and science achievement compared to the classrooms with other supportive patterns.

Olutosin Solomon Akinyemi Adeniran G Adewusi

Influence of pre-service teachers' interactive use of content-specific knowledge components from students' point of view

This paper reports on the qualitative examination of students' views about the influence of pre-service teachers' teaching on their learning of Organic chemistry. The examination employed the content-specific knowledge components of topic specific pedagogical content knowledge (TSPCK) (Mavhunga & Rollnick, 2013) as a theoretical lens. The participants were three pre-service teachers who delivered two lessons each focusing on Organic chemistry during a school-based practicum attended by 74 physical sciences Grade 12 students. The data collected were the video recordings of the pre-service teachers' teaching, stimulated recall interviews conducted with the pre-service teachers, and students' views collected through focus group semi-structured interviews following the pre-service teachers' teachings. The findings revealed that the students' descriptions of what contributed to their learning reflected, in a similar way, the pre-service teachers' understanding of the importance of the interactive usage of content-specific knowledge components of TSPCK as a key factor. The implication and recommendation for teachers are that the possession of different content-specific knowledge components of TSPCK as a the factor contributing their learning.

Mark O Akubo Sherry A. Southerland

Gender Dynamics During Discourses in SCALE-UP Format of Physics Course: An Exploratory Single Case Study

The underrepresentation of women in STEM more generally and in physics specifically has been well established and the field remains challenged by the negative consequences of this underrepresentation. A number of curricular and pedagogical innovations have shown success in supporting student learning, and some such as SCALE-UP or (Studio Physics) have been found to narrow the learning gaps between men and women. SCALE-UP stands for student-centered activities for large enrollment undergraduate programs. More research is needed to understand this innovative classroom and pedagogy in terms of gender equity. In this exploratory single case study of gender dynamics in a small group, we had the purpose of identifying and describing patterns in gender dynamics, and to understand what meanings students ascribed to the gender interactions. Using Vygotsky's socio-cultural theory and discourse analysis, we analyzed audio/video and interview data on a group of (one woman and two men). We found that Kay (the woman) orchestrated all the active positive gender dynamics. Subtle negative and active positive gender dynamics were associated in episodes, and the men were asymmetrically involved with both positive and negative dynamics. These findings extend our understanding by revealing interconnections among gender equity, epistemological framing, and physics identity.

Sulaiman M. Al-Balushi Rashid S Almehrizi

Studying girls' achievement outperformance in Oman: An exploration of attitudinal perceptions towards Science and learning

The current study explored girls' achievement outperformance in Oman concerning different attitudinal self-perceptions towards Science and learning. The study included 538 grade nine students in Oman (320 girls and 218 boys). Participants completed six different measures. One instrument measured their science achievement, and five instruments measured their self-perceptions of their attitudes towards Science, attitudes towards learning, self-regulation, metacognitive awareness, and self-efficacy of learning. Findings showed that a significant gender gap in favor of the girls existed in all five self-perceptions variables studied in this research. Furthermore, a significant interaction of gender existed with participants' self-regulation and attitudes towards Science. Boys with low self-perceptions in self-regulation and attitudes towards Science achievement scores than girls with low self-perceptions in these two measures. Careful attention should be given to boys' attitudinal self-perceptions and their engagement in science learning.

Annie Allen Clarissa Deverel-Rico

Learning to Teach with Storyline Curriculum Materials

Current science reform efforts call for significant shifts in teaching science that emphasize learning about science to figuring out science and cultivating students' interest in and identities in science. Providing sustained, curriculum-embedded professional development can support teachers in making those shifts, but until recently, few materials existed that embody the vision of A Framework for K-12 Science Education and that are supported by extended opportunities for teacher learning. We present a project that has provided teachers with high quality, phenomenon-based, middle school science units, along with sustained, curriculum-based professional development over the course of a three year period, focusing on the shifts in their curriculum implementation over time. Drawing upon interview data conducted with 36 teachers who participated in at least two years of this professional development, revealed patterns in the shifts teachers described with their overall approach to teaching science and with particular aspects of teaching the middle school science units. The findings from this paper can inform curricular design and professional learning design and contribute to helping all learners achieve science literacy.

Francisca A. Allename Peter A. Okebukola

Underachievement in Difficult Concepts in Biology: Can CTCA be the Way Out?

This study focuses on why students find nervous system as a difficult concept in biology in Nigerian secondary schools and to determine the efficacy of the culturo-techno-contextual approach in improving achievement of secondary school students in nervous system. Recent studies have shown that students perceive nervous system to be a difficult concept in senior secondary school. (Author, 2020). The objective of this study focuses on determining the effect of CTCA on students taught nervous system and those taught using lecture method. The study adopted a quasi - experimental pretest and post-test research design. The treatment lasted for four weeks. 36 students (19 boys, 17 girls)

were used for the experimental group while 29 (14 boys, 15 girls) students were used for the control group. The instrument used in data collection was Nervous System Achievement Test (NSAT) and Nervous System Interview Guide (NSIG) from two secondary schools in Lagos state. The result of the study showed there was a statistically significant difference in the achievement of students taught nervous system using the CTC approach and those taught using the conventional lecture method with the result showing F (1,62) = 27.29; p<.05. Implications for the study were highlighted.

Hiya M. Almazroa Eman M Alrwaythi

SCIENCE TEACHING PERFORMANCE: INVESTIGATING GENDER, QULIFICATION, AND TEACHING EXPERIENCES

The Saudi Teaching Observation Protocol (STOP) was applied to determine science teachers' performance and whether or not these performances differ according to gender, professional education, and teaching experiences of teachers. The STOP was administered to 286 randomly selected science teachers who teach science in elementary and secondary schools. The sample consisted of 153 male teachers and 136 female teachers. As for years of experience, 42 teachers had less than 5 years experience, 79 teachers had 5 to 9 years experience, 66 teachers had 10 years to less than 14 years experience, and 102 teachers had 15 years or more experience. A stratified sample was drawn that was representative of the five provinces of Saudi Arabia. The T-test showed that there were statically significant differences in science teaching performance due to gender in favor of female teachers. Moreover, T-test showed no significant difference between teachers who had professional education and teachers who graduated from science college. F-test showed no significant differences between teachers who had professional education and teachers with different teaching experience. The study has implications related to pre- and in-service teacher education programs.

Oshra Aloni Michal Zion

The Effect of Multi-Faceted Holistic Approach in Science Instruction on Students' Achievements, Preferences, and Needs

The distinct, and yet, multiple variables that characterize each student create an environment of multiple personalities that influence the effectiveness of instruction and the depth of learning. The challenge is to make learning, accessible and welcoming to all students. In response to the inclusion approach, the Multi-Faceted Holistic Approach (MuFHA) has been developed. The MuFHA maps pedagogical methods recognized in literature as contributing to the learning of all students (e.g., typical, having a learning disability, struggling, gifted) according to four dimensions that represents the whole learner: cognitive, social, emotional, and sensorimotor. The current study examined to what extent did the MuFHA based instruction in science studies affect students' achievements, their metacognitive awareness, and address students' cognitive, social, emotional, and sensorimotor needs? 209 middle school students (14–15 years old) assigned to intervention and comparison groups. The study applied a mixed method approach. Findings show that the MuFHA, coupled with the application of various instructional methods, contribute to addressing students' diverse needs and preferences. Auditory learning is the least preferred by students, although it's prevalence. MuFHA based instruction which

addressed the cognitive, social, emotional, sensorimotor needs of all students, contributed to significant achievements improvement of all learners, especially low achievers.

Alicia C. Alonzo

Supporting Pre-Service Teachers' Attention to All Students' Ideas Using a Learning Progression Approach

Learning progressions (LPs) have been suggested as a support for teachers' formative assessment practices. However, as models, LPs simplify complex phenomena—e.g., representing a limited set of student ideas and learning pathways, raising concerns about whose thinking and learning is privileged. This is particularly problematic for a key affordance of LPs—informing teachers about what ideas might be particularly important to attend to—because teachers may attend only to ideas from students from the dominant culture, potentially excluding students who are already marginalized in science classrooms. Pre-service teachers (PSTs) may be particularly vulnerable to this narrowing of attention. We engaged PSTs in a set of LP-informed activities designed to support their noticing and interpretation of student ideas. We investigate how—following these activities—two PSTs noticed and interpreted student ideas about force and motion. We provide evidence that our LP-informed approach may support PSTs in identifying ideas that are and are not represented in the LP. However, the LP provided differential support for PSTs' problematization of evidence of student thinking: they more often sought to clarify students' thinking about the LP-aligned ideas, so there is still potential for marginalization of non-LP ideas and the students who hold them.

Jessica L. Alzen Kelsey D. Edwards

Variations in the Co-occurrence of Epistemic Agency and Collective Enterprise

Science education reforms prioritize meaningful student engagement in the practices of science. To accomplish this necessitates that students be positioned as epistemic agents in constructing, using, and revising science knowledge through knowledge-building practices. These priorities require teachers to make shifts in pedagogy that support students in these agentive experiences. However, these shifts also create challenges for teachers in engaging students' ideas while also ensuring that they meet established content standards. Models of how teachers can navigate these tensions are needed to help teachers adapt their practices. In this paper, we study three teachers working with the same instructional materials and professional development experiences designed to support student agency. Our primary goal is to describe variations in how these teachers navigated the tension between giving students agency to pursue their own questions while also meeting the teachers' own goals for students in an instructional unit. We hypothesize about how the teachers' differential practices to support knowledge-building in the class as a collective enterprise may influence variable opportunities for students to experience epistemic agency as well as experiences with science practices.

Arnau Amat Alberto Bellocchi

The Role of Emotions in Science Teacher Education and Professional Development

Science teacher emotions have been increasingly investigated vis-à-vis emotions in teaching. However, emotions in science teacher learning and the role they play in teacher education and professional development (PD) have seldom been investigated, despite accumulating evidence demonstrating the critical role emotions play in students' learning processes and outcomes. This symposium brings together an international group of scholars to present recent findings and to discuss how emotions are involved in the process of science teacher learning, how they shape — and are shaped by — different features of the context, and the implications these might have for teacher education and PD. The presentations include a systematic review of literature on the role of emotions in pre-service and inservice science teacher education, followed by three empirical studies of: pre-service teachers' emotional expressions and the ways facilitators manage them; and the affective dynamics in the PD journey of one science teacher as a doer and a teacher of science. Collectively, the four presentations, and the discussant commentary, will shed light on the critical role emotions play in science teacher professional learning.

Walter Aminger

Cultivating Discourse of English Learners During the Enactment of Cognitively Demanding Work

Students designated as English learners (ELs) are the fastest growing group of students in K-12 public schools across the United States (NGSS Lead States, 2013). In this study, we investigated how preservice secondary science teachers supported the discourse demands of tasks implemented as part of their edTPA lesson cycle (a national performance-based assessment for preservice teachers). We examined how participants integrated the NGSS science and engineering practices and content. We found that all six participants engaged their students in five to seven other practices (e.g., using mathematics and computational thinking). Moreover, we found that our participants were willing to take responsibility for supporting the academic language demands of the cognitively demanding tasks they implemented, and that they were able to draw on a robust range of strategies. As such, our findings suggest that teacher education programs must carefully attend to the balance between supporting academic language and supporting rigorous content learning for ELs. Finally, our study also suggests that if secondary science teachers are expected to help their students successfully engage in scientific discourse, teacher education programs will need to provide preservice teachers with an even deeper understanding of how to scaffold the complex linguistic demands of discourse.

Lori Andersen

From Practical to Metacognitive Strategy: Meta-epistemic Discourse and Crosscutting Concept Supports in Curriculum

Although exemplars of CCC support in curricula are emerging a clear framework to guide their use has not been developed. The paper describes patterns of CCC supports and the metacognitive experiences that support students' epistemic thinking. Document analysis was used to examine the Garbage unit, consisting of nine lessons documents with 93 activities that are designed for a total of 24 class periods. Crosscutting concept supports were coded within each activity as implicit or explicit and by the highest level of thinking (i.e., practical, epistemic cognition, metacognitive knowledge, metacognitive strategy).

Eighty-two activities (88%) had CCC supports. Explicit support was more common (n=84, 90%). Observed patterns included explicit-practical (n=30, 32%), explicit-metacognitive knowledge (n=21, 23%) explicit-epistemic cognition (n=20, 22%) and explicit-metacognitive strategy (n=2, 2%), which was supported by theory. Across the three levels of thinking, seven patterns were identified that represent types of metacognitive experiences within curriculum (i.e., explaining as directing use, modeling as directing use, teaching how to use with a rationale, describing why scientists use, stating how scientists use, teaching how to use without a rationale, and mentioning). A deeper understanding of CCC supports provides valuable insight that has implications for science education.

Sage Andersen Brad Hughes

The Impact of Arts-based Science Instruction on Emerging Multilingual Students' Achievement in Elementary Science

Recent reform efforts and the NGSS emphasize learning through engagement in science practices, which require students to use language in new and complex ways. These increasing language demands can present a challenge for emerging multilingual learners (EMLs) who are learning science content and academic language in addition to the English language and whose semiotic resources teachers often do not know how to tap into. Research into instructional methods for supporting EMLs in science promotes the use of multimodal (linguistic and non-linguistic) instruction to increase students' access to the material and to provide opportunities for students to demonstrate what they know. Arts-integrated science instruction, utilizing the visual and performing arts (VAPA) may provide new, creative multimodal means for EMLs to engage with science content and communicate their ideas using all their semiotic resources. To explore this potential, the current study utilized a randomized control trial to compare the impacts of a VAPA curriculum with an inquiry-based curriculum on EML achievement in elementary earth science. Results indicated significantly higher science achievement for EMLs who participated in the VAPA-integrated condition compared with the inquiry control condition, suggesting that the use of VAPA-integrated science methods may hold significant affordances for EMLs.

Sage Andersen MarÃa GonzÃjlez-Howard

Impacts of a science teacher's curricular enactment and innovation on students' opportunities for scientific sensemaking

Notable to the shifts called for by reform-oriented standards including the NGSS, is the positioning of students as competent sensemakers, with learning centered around students' ideas as they make sense of scientific phenomena. Educative curriculum focused on both teacher and student learning, and aligned to the NGSS, has the potential to help teachers shift instruction in ways that support this vision for science learning. However, teachers use and adapt curriculum in a variety of ways based on personal and external factors and to meet the needs of their students. As such, it is important to consider how teachers' use and enactment of the curriculum may impact students' opportunities for authentic sensemaking around big science ideas. This study utilized a case study methodology to explore a middle school science teacher's enactment of a reform-oriented curriculum in his classroom. Findings revealed that changes made by the teacher during enactment functioned to provide students with more opportunities for sensemaking, compared to the intended curriculum, in which they were either solely

or jointly responsible for that sensemaking, while also moving sensemaking away from individual students and towards shared, whole group sensemaking opportunities. Implications for instructional change and students' opportunities for scientific sensemaking are discussed.

Vanessa De Andrade Yael Shwartz

Collaborative drawing to enable and enact reasoning-in-action.

Drawing is recognized as a powerful tool to learn science. Although current research has enriched our understanding of the potential of learning through drawing, scarce attention has been given to how collaborative drawing facilitates the development of students' reasoning. Informed by theories on distributed and embodied cognition, this presentation examines how collaborative drawing enables and supports a process of reasoning-in-action. This article presents a pair of middle school students who jointly attempted to understand and explain a chemical phenomenon by creating a drawing collaboratively and reasoning with it. Using a fine-grain multimodal analysis, we examine how collaborative drawing enables an integrated sequence of embodied actions on the drawing that works to generate a real-time animated model. We argue that collaborative drawing has a potential for learning, not restricted to the cognitive process related to the activity of creating external visual representations on paper; instead, the benefits of drawing lie in action in space.

Julie Angle Rachel Hartnett

Strengthening Teachers' Confidence to Mentor Students in STEM Research and Science & Engineering Fair Competitions: PD Models for In-person and Virtual Formats

For over 60 years, students have participated in science and Engineering (S&E) fair competitions designed to foster their interest in STEM fields. However, due to limited professional training, not all science teachers have the confidence, knowledge or skills to mentor students in research or coach them through S&E fair competitions. Using responses from a needs-assessment survey, this paper describes the development and execution of teacher workshops designed for middle school and high school teachers interested in starting a science fair program at their school or strengthening their current program. Year-1 workshops were conducted in-person, while year-2 workshops were conducted in a virtual format due to the COVID pandemic. This study reports the changes in teachers' levels of confidence in three categories: fair logistics and infrastructure, conducting research, and mentoring skills. Teacher self-reported gains in competency were quantified by calculating the normalized change in post-survey and pre-survey scores on Likert-scale statements. Results suggest that while teachers showed significant gains in both the in-person and virtual formats, larger gains occurred when the workshops were offered in a virtual format. Interestingly, participates who attended all three workshops reported smaller gains on average than participants who attended only one workshop.

Len Annetta Matthew Militello

School Leaders Learning How to Observe Science Teachers Using Equitable Discourse Through Virtual Reality

The purpose of this study was to explore the utility of a virtual classroom for school administrators to practice their ability to identify and collect evidence on equitable academic discourse with science teachers. Through Virtual Reality (VR), we developed training scenarios for school administrators to learn how to observe and specifically what to look for when observing science teachers as opposed to observing teachers in non-lab courses. This study revealed that VR ability to change practice is a matter of fit. Professional development (PD) fit matters. The content of PD and the context of the setting must intersect, and professional support must link to teacher needs. This study also indicates users' appreciation for the opportunity to practice classroom observations in a risk-free environment. We provide insights from users regarding the experience and affordances of the virtual setting on their classroom observation skills.

Pavlo D. Antonenko Kara Dawson

CryptoComics: Design of an Integrative STEM+C Transmedia Curriculum

This paper addresses the need for educators to generate more and better solutions for integrating STEM+C disciplines in afterschool programs. In project CryptoComics, we explored and determined that cryptology may be a useful pathway to introduce children as young as 8 years old to authentic STEM+C problems, processes, and tools, and get them excited about the role cryptology and cryptologists in the past, present, and future of our society. This design case paper introduces cryptology as an integrative STEM+C curriculum. We position transmedia narrative as a powerful method of telling a single story across media and modalities to create a unified, highly captivating learning experience with each medium making a unique contribution to the unfolding of the story and placing the learner in the state of flow. We discuss the proin ciples guiding the design and development of CryptoComics and we conclude the paper by discussing lessons learned from our design-based implementation research and implications for engaging young, elementary-aged students in STEM+C problem solving and for further research and practice on integrative STEM+C in informal learning settings.

Kristine A. Antonyan Pavlo D. Antonenko

The Science of Data Visualization Comprehension: Analysis of Seminal Theoretical Frameworks

Comprehending data visualizations is an important skill because the amount and nature of data sources continue expanding and data analysis is required in STEM education and its many 21st century careers. To inform future research into data visualization comprehension, this study examined what theories have been used to frame empirical research on data visualization comprehension in the last 40 years. The theories of data visualization have focused on delineating perceptual and cognitive processes that the learners perform for making sense of visual data. The theories focused on (a) addressing the sequencing of such processes with the cyclical and iterative nature of visualization comprehension, (b) levels of the task complexity of data visualization comprehension, (c) the role of graph schemas supporting the comprehension process, and (e) the spatial-to-conceptual inferences, where the spatial attributes of data visualizations hinder their conceptualization. The findings have important implications for identifying new directions for empirical studies with emerging data visualizations with seductive

elements and exploring how people process those visualizations by applying new approaches to studying the cognitive and perceptual affordances of data displays.

Kristine A. Antonyan Poorya M. Shidfar

The Role of Individual Differences in Working Memory Capacity When Comprehending Visualizations With Relative Data and Seductive Details

This study explored the effects of verbal, visuospatial, and mathematical working memory capacity on the data visualization comprehension of learners as they synthesized COVID-19 trends analyzing data visualizations with seductive details and relative data representations. The learners with the ability to recall verbal information while also performing textual tasks were more efficiently comprehending data visualizations with seductive details not related to COVID-19, and more accurately comprehending visualizations with COVID-19 relative data representations (percent change). The learners with the ability to better recall verbal information while also performing mathematical operations were more efficient, but not necessarily accurate in comprehending visualizations represented with both seductive details and relative data. Finally, the learners with the ability to recall visuospatial objects while also performing some visual tasks were more efficient in comprehending visualizations represented with relative data and COVID-19 non-related seductive details. These findings indicate (a) the destructive nature of non-related, and the supportive nature of related seductive details, (b) the positive impact of learners' visual abilities on data visualization comprehension, and (c) the lack of knowledge about the concepts of percent increase represented with data visualizations. These findings have important implications for teaching and learning science data as society is grappling with more complex science data using new data visualizations.

Tasneem Anwar

Visualizing STEM in Pakistan: Insights from a Professional Development for Conceptualizing STEM

This case study aims to share the spectrum of STEM conceptions that were visualized by six teams of teachers at a public school in Sindh Pakistan who participated in a ten-day long STEM-focused professional development. Multiple data sources including pre/post survey were administered to gather data on initial and final understanding of teachers about integration of STEM, daily written reflections were gathered from teachers and STEM Model Representations were periodically collected from participants to view their understanding of integration of STEM at three different times. This case study offers two significant takeaways: 1). showed the gradual and varied evolution of teachers' conceptions of STEM, 2). highlighted the features of professional development that best supported teachers in visualizing STEM. These takeaways have direct implications for teacher educators for national level implementation of STEM in Pakistan. Whereas this study offers interesting insights for the international researchers especially the North American researchers allowing them to visualize the transfer and adaptation of STEM reform in a country that is one of the most recent adopters.

Erik Arevalo Meghan Macias

Examining Middle School Teacher Implementation and Enactment of the NGSS: A Mixed Methods Study

The NGSS represent a considerable shift away from traditional science teaching and learning, requiring collaboration and partnership between teachers, administrators, curriculum developers, and professional development leaders, as well as other stakeholders. The complex nature of this collaboration presents challenges in how to best support implementation and enactment of the NGSS within classrooms. In order to address this need, this paper reports on a mixed method study that began with a qualitative analysis of the literature to inform a quantitative analysis of survey items. From this analysis, we developed a tentative quantitative model that describes how teacher utilization of educational practices influences and impacts NGSS enactment, as measured by teacher reported frequency of enacting CCC's, SEPs, and DCI's. Results show that key variables such as preparedness to teach equity, access to collaborative professional learning communities, district, administrator, and state support, and the resources available to teachers all had significant impacts on the enactment outcomes. This paper will be useful in identifying key areas in educational practices that can be further developed and refined to support teachers in their enactment of the NGSS.

Anna Maria Arias Jessica Stephenson Reaves

Elementary Preservice Teachers Investigating Local Phenomena and Problems: Envisioning Opportunities for Equitable Student Sensemaking

Contemporary reforms in science education emphasize the importance of supporting equitable sensemaking through privileging ways of knowing science that honors students' ideas, experiences, and community resources. Recognizing the challenge of learning to do this work, this paper set investigates how elementary preservice teachers (PSTs) can learn the knowledge and practices that facilitate more equitable learning opportunities. Paper 1 examines PSTs' engagement in equitable sensemaking of local phenomena as learners and how the PSTs discuss using local resources to engage students in making sense of local problems. Paper 2 focuses on PSTs' subject matter knowledge required for noticing and using students' ideas in equitable ways. Paper 3 examines how PSTs' thinking about how to leverage students' ideas and resources change over the course of a semester. Paper 4 investigates how PSTs noticed opportunities for promoting equitable sensemaking within their enacted lesson plans. By focusing on different elements involved in learning to support equitable sensemaking, this paper set illuminates the complexity of this work, and thus, the multiple dimensions that require consideration in elementary education. The findings have implications for teacher educators and curriculum developers working to prepare teachers to develop the practices and dispositions that move toward more equitable teaching.

Itsik Aroch Dvora Katchevich

Identification and characterization of the essential knowledge domains for online chemistry teaching during Covid-19 pandemic

The massive shift towards online teaching because of the Covid-19 pandemic raised the question whether there are essential teacher knowledge domains for online teaching. In this paper, we present

an explorative qualitative study based on interviews with 11 expert chemistry teachers that described their online teaching experience during the first 6 months of the pandemic. We identified nine knowledge domains: facilitating and tracking student engagement, assessing student knowledge, identifying activity effectiveness, personalizing teacher-student and student-student communication, retooling content, teaching for student self-regulation, reinventing teacher identity, developing digital literacy, and data-driven teaching. These knowledge domains were realized in three levels (replication, transition, and transformation) according to the level of technological utilization and innovation. It was evident that teachers needed a more general perspective than the one provided by the TPACK framework, one that extends beyond their discipline and encompasses all the teachers' practices and interactions with students. The findings of this study are aimed to serve as a baseline for the essential tools and practices to prepare teachers for online teaching. Based on the nine identified knowledge domains for online teaching, we plan to develop a model for teachers' professional training to teach online.

Andrea Ash Gavin W. Fulmer

Response Shifts in Measurement of Teacher Growth

Did something other than professional development (PD) create the change in teachers' scores? Teacher learning can be difficult to analyze over time: as time passes, measurement can be affected by many factors (e.g., exposure to instrument, external changes). This can create a response shift, which results in different "measuring sticks" for each occasion. With different measuring sticks at each occasion, there can ultimately be change in teacher scores not due entirely to change in ability. While response shifts – also known as measurement non-invariance– are well-studied in other contexts, little investigation has been done on how they might affect measurement in PD settings. This study used item factor analysis, measurement invariance analysis, and the language of response shifts to investigate whether teacher responses on an instrument measuring teacher learning can be compared across occasions. Findings indicate that response shifts did occur, but were limited enough to facilitate comparison across occasions using an appropriate measurement model. Importantly, we determined that after accounting for response shifts, growth in teachers' learning was no longer significant after the second occasion. Many research opportunities exist to expand the field's understanding of why response shifts happen in PD and how they might impact score interpretation.

Osnat Atias Ayelet Baram-Tsabari

Scientists' and Teachers' Perceptions of Costs and Benefits in School-Based Citizen Science

Citizen science holds significant impacts for science, citizens, and society. Potential benefits for participating citizens, encompassing a range of affective, cognitive, and behavioral learning outcomes, guided the inclusion of citizen science in schools' curricula. This study examines scientists' and teachers' perceptions of costs and benefits in school-based citizen science projects, seeking to promote school-based citizen science as a sustainable and mutually beneficial endeavor that fully materializes the "learning-by-doing" approach to science education. Study participants includes nine pairs of scientists and teachers that collaborated in mutual school-based citizen science projects. Participants answered an online questionnaire for identifying perceived costs and benefits in an analytical framework based on

the Expectancy-value theory of motivation. Our main finding was that teachers regarded students as principal beneficiaries of the projects, while deriving high intrinsic (enjoyment), utility (usefulness) and attainment (identity-based importance) values. Scientists mostly reported high intrinsic and attainment values, with a lower appreciation of derived utility value. These results challenge the notion of mutual benefits in school-based citizen science, calling forth strategies for designing more scientifically-centered projects with the ultimate goal of allowing students to become authentic contributors to scientific research.

Osnat Atias Ayelet Baram-Tsabari

Motivations of Scientists and Teachers to Collaborate in School-Based Citizen Science Projects

Citizen science offers significant impacts for science, citizens, and society. For participating citizens, citizen science may induce a range of affective, cognitive, and behavioral outcomes, guiding the inclusion of citizen science in schools' curricula. Such school-based projects can face difficulties in balancing scientific and educational goals. This study examines scientists' and teachers' motivations for school-based citizen science, seeking to promote this endeavor in a mutually beneficial manner that involves students in impactful scientific research. Nine pairs of scientists and teachers that collaborated around mutual projects participated in the study. Each participant ranked a list of motivations for school-based citizen science according to personal importance. Results show that student-centered objectives were major motivational drivers for all participants, both scientists and teachers. Scientific goals were highly prioritized by 7 of the 9 scientists and by a few teachers. These results are in accordance with other reports of school-based citizen science projects, where educational goals seemed to overcome scientific ones. We hypothesize that the school-based setting of the projects pushes forward their identity as educational endeavors. This impedes the ultimate goal of school-based citizen science, to have students offer authentic contributions to scientific research.

Mary M. Atwater

Unifying Our Community through Science Education

The first part of the 90-minute hybrid virtual/in person administrative session sponsored by The Continental and Diasporic Africa in Science Education RIG (CADASE RIG) includes a 45-minute plenary presentation with an invited speaker including time for a question and answer period. The presentation will be in line with the CADASE theme "Unifying Our Community through Science Education". The second half of the administrative session will include a poster session in which faculty members and doctoral students from U.S. Historically Black institutions and CADASE RIG and NARST members will share their work that focus on the RIG's theme: "Unifying Our Community through Science Education". The poster presenters using the virtual format will probably be divided into rooms and the poster presenters at the conference will present in the assigned room for the CADASE Administrative Session. Notes: Mr. Jonathan Hall will work with the NARST technical team to assist in the smooth transition using these two formats. If a workshop is offered by NARST for using the ZOOM platform, Jonathan Hall, Mary M. Atwater, and others on the CADASE Steering Committee will participate in the NARST workshop for its ZOOM platform. If the Program co-chairs offer an opportunity for RIGs to have social events during the 2022 NARST conference, then the CADASE Steering Committee and the Graduate Student Committee will be interested in sponsoring such events. Contact Mary M. Atwater, Chair of CADASE RIG for additional information. Suggested Day/Time: March 28, 2022 from 1:45 -3:15 pm EST (10: 45 British Columbia time) or March 29, 2021 from 1:45-3:15 EST (10: 45 British Columbia time) Tentative Schedule: Major activities and approximate times First choice: First day of the NARST Annual International Conference from 1:45 – 3:15 EST; 10: 45 British Columbia time; and 7:45 pm Nigerian time. Second choice: Second day of the NARST Annual International Conference from 1:45 – 3:15 EST; 10: 45 British Columbia time; and 7:45 pm Nigerian time. Second choice: Second day of the NARST Annual International Conference from 1:45 – 3:15 EST; 10: 45 British Columbia time; and 7:45 pm Nigerian time. (NO CONFLICTS WITH OTHER SCHEDULED ADMINISTRATIVE SESSIONS OF THE LATINO/A RIG (LARIG) and INDIGENOUS SCIENCE KNOWLEDGE RESEARCH INTEREST GROUP (ISK-RIG)

Shirly Avargil Arunika Saxena

Students' Conceptual Models in the Context of Air-Quality Learning Unit

Engaging students in developing and using models encourages them to reflect on their own knowledge and understanding of how science and scientists work. However, for students to match and map the correct model of the given abstract phenomenon is a difficult task that can be learned through supportive instructional materials. This research investigated how middle-school students' abilities of developing and using models manifested through their drawings and explanations in learning chemistry, in the context of the PBIS Air-Quality learning unit. Eighth-grade middle school students (N=436) were asked to draw and explain a conceptual model of a chemical phenomenon. We designed a rubric for scoring each student's explanation and addressed the following aspects: chemistry understanding levels, the system surroundings, and students' modeling abilities. The study showed how 8th grade students can construct drawings along with explanations to explore a daily phenomenon. The students in this study learned through instructional materials that encouraged them to express their mental models of a scientific phenomenon through their drawings, as aids for their explanations. Students creation of their own drawings engage them in identifying the core components of the phenomenon and explored their thinking and understanding of science content.

Farnaz Avarzamani Mila Rosa Librea Carden

Moroccan Science Professors' Nature of Science's Understandings and Perceptions on its Instruction for Preservice Teachers

The study explored science and/or science education professors' nature of science's (NOS) understandings and perceptions on NOS instruction within a series of professional development. Using repeated measures design, findings showed a general increasing trend from pretest to posttest across all NOS aspects and particularly significant changes in understanding observations and inferences, sociocultural and creative NOS aspects. Participants showed significant improvements in one or more NOS aspects. As for participants' perceptions on NOS instructions, findings did not show a significant change in participants' means across PDs. While the retrospective items suggest a strong improvement in knowing good NOS activities, instructional perspective changes may take longer to develop and be highly dependent upon first changing NOS understanding. More research can help improve the efficacy of PD methods and help identify key constructs that are most relevant for perceptions of NOS instruction.

Ehud Aviran Ron Blonder

The influence of a personalized online environment for chemistry teaching and learning on students' outcomes

Following the initial lockdown beginning April 2020, the Israeli educational system was forced to cease in-class learning. As the pandemic raged on, the following year began remotely and eventually switched back to classroom teaching. The current study focuses on high school chemistry students and how their attitudes and self-efficacy regarding educational technology have changed during this year. Utilizing a unique system for personalized teaching and learning of chemistry (Chem-PeTeL), students from across the country responded to an attitude and self-efficacy beliefs questionnaire, at the beginning and at the end of the school year. Paired t-test conducted on 139 students responses showed significant rise in attitudes towards the use of educational technology for chemistry learning, as well as gains in self-efficacy to utilize such technology for their own learning. An initial analysis of responses to open-ended questions from the questionnaire further supports these findings, shedding light on what specifically made remote learning via Chem-PeTeL successful for some, but not for others. Insights from this work related to personalized online chemistry learning can be further implemented in future studies, research and practice related to online and remote chemistry teaching as well as to the discussion on inclusive teaching.

Lilach Ayali Shulamit Kapon

Mathematical Modelling in Physics Education

Mathematical modeling is acknowledged as a fundamental practice in science education standards. Teaching students how to construct and use mathematical models is a central goal of physics education. However, there are ongoing debates on how best to incorporate modeling into physics instruction, and modeling is considered one of the most challenging processes for physics students. This paper reviews conceptualizations of mathematical modeling in the science and physics education literature. This review covers 54 articles published in 11 leading peer-reviewed journals since 2000, that discuss mathematical modeling either as the focus of the investigation or as an illustrative example, component or outcome of the investigation. A content analysis was employed to identify educational goals and activities related to mathematical modeling as conceptualized in the articles. The frequencies of goals and activities were documented, the associations between goals and activities were calculated, and Principal Component Analysis was applied to aggregate the activities into meaningful clusters. The analysis suggests that the use of mathematical modeling in the instruction of physics is more highly influenced by educational approaches that focus on the learning of science than educational approaches that focus on learning to do science.

Sevgi Aydin Betul Ekiz Kiran

PRE-SERVICE TEACHERS' LEARNING TO INFUSE ENGINEERING INDICATORS INTO STEM LESSON PLANS

This study investigates pre-service teachers' efforts to integrate engineering indicators into their lesson plans through a 13-week research-based and engineering-infused training. Participants were 13 pre-service chemistry teachers enrolled in an integrated STEM course. During the training, information

about the engineering profession and how engineers work were emphasized. Participants engaged in six integrated STEM activities including engineering design. Moreover, the participants had three chances for STEM lesson plan analysis and STEM lesson planning experience with mentors. Lesson plans prepared by the participants before and after the training were analyzed through deductive approach using Framework for Quality Engineering Education and inductive approach by forming four categories (ranging from a complete engineering lesson to a science lesson with no engineering link). The results showed that none of the pre-plans included either engineering or any indicators. However, after the training, all post plans integrated engineering and design processes to some extent. Moreover, the teamwork, process of design, communication, and concepts of engineering indicators were integrated by almost all participants. Yet, ethics and the impacts of solutions on people and environment were often missing in the post-plans. Training including different experiences seems promising for teachers learning to integrate engineering into STEM lesson plans.

Jean-Philippe Ayotte-Beaudet Abdelkrim Hasni

Assessing Elementary Students Ability to Make Informal Observations About Living Organisms Outdoors

To help students build bridges between their learning and their everyday surroundings, teachers could focus on developing students' ability to make scientific investigations, like scientific observation. Outdoor environments could be the starting point for to make these kinds of learning. Our research aimed to compare elementary students' ability to make informal observations about living things in their home environment at the end of a learning experience and two months later. We recruited fifth- and sixth-grade students aged between 10 and 12 years old (n = 116) in the province of Quebec, Canada, during the first COVID-19 lockdown. Students were involved in a citizen science project from home. Data was collected through structured interviews. As a result of our analyses, we defined three categories of informal observations: (level 1) informal observation about living organisms leading to a factual description, (level 2) informal observation about living organisms leading to context-specific inference, and (level 3) informal observation about living organisms leading to inference in other contexts. We hope our results will be contributing to the development of methodological tools to test hypotheses that are generally accepted, but that have never been clearly empirically validated.

Saiqa Azam Karen Goodnough

Development of Teacher Identity: From 'I can teach Science' to 'I can teach STEM'

This qualitative study aimed to investigate preservice elementary teachers' STEM teaching identity development during their participation in the science methods course, STEM course, and Field teaching. A case study design aimed to examine the experiences that contributed to the formation of STEM teaching identities of three participants in a newly design teacher education program in a public university in the Atlantic region in Canada. Data collected over a year from multiple courses included (i) questionnaire about views and perceptions of STEM, (ii) written reflection, (iii) interviews transcripts, and (iv) artifacts created by PETs. Feiman-Nemser's (2008) thematic framework of learning to teach was used as an analytical lens to analyse data. The analysis of the data revealed that experiences and interactions within science methods course, STEM course, and Filed teaching accounted for the changes in how and in what the ways the three preservice elementary teachers think, feel, know, and act as a

teacher of science/STEM. Findings indicate the importance of the framework of learning to teach in analysing preservice science teachers' identities. The study includes implications for preservice teacher education programs and research.

Yejun Bae Marcelle Siegel

College Students' Sense of Belonging in the STEM Learning Ecosystem: Classroom, Department, and University Culture

This study focuses on how students felt in science, how culturally relevant the programs seemed, and how any biases or microaggressions were experienced in the university. Based on this, we developed a survey instrument that is capable of showing how STEM college students perceive their classroom and campus experiences (classrooms, programs, and institutions). By conducting an exploratory factor analysis and bifactor analysis for graded response data, a three-trait model with 18 items was confirmed. Three latent traits in this study illuminate the critical aspects of belonging, which gauges the overall inclusive atmospheres of STEM learning environments. The findings showed that this study validated a survey instrument to not just find out whether students feel general belonging or not, but to elicit a more nuanced understanding of how students feel about the support and whether they feel restricted or encouraged to grow.

Grace K. Baker Emma J. Jacobson

Supporting Discussion-based Science Practices for Special Education Students

Traditionally, special education students have a lower science achievement compared to non special education students, but special education students have been found to benefit from discussion-based science classrooms (Taylor et al., 2011). This study follows two students with IEPs and a paraprofessional as they work together on an online plate tectonics unit. The goal of this study is to understand how the students' sensemaking, progressive discourse and overall science talk changed as they worked individually, with their peers, and with their teachers. Analysis suggests that peer-peer and teacher-peer discussion spark more robust science talk and sensemaking in the special education student's work than when they are working individually. Specifically, our study suggests that teacher's questioning can support special education students to make connections and build their confidence to participate more fully in whole class settings. Our study also shows the importance of inclusive and safe environments for special education students to succeed.

Meena M. Balgopal Elizabeth Diaz-Clark

How some early-career STEM teachers achieved agency during the COVID-19 pandemic

The COVID-19 pandemic has inflicted disruptions for teachers, evoking a range of responses. Teachers were required to learn new skills, modify their instructional approaches, and discover innovative ways to engage their students, all while managing their own professional and personal needs. To understand

how teachers perceived barriers or opportunities needed to achieve professional agency, we administered three surveys throughout 2020 to 155 early career science, technology, engineering, and math teachers, who taught in high needs school districts and received scholarships from the National Science Foundation. A preliminary analysis of open-ended responses thus far indicates that teachers who demonstrate having achieved agency: (i) are aware of how to balance their professional and personal needs and (ii) were asked to teach in only one modality (only online or only in-person). In general, teachers were most concerned about how to juggle meeting their students' needs, their professional needs, and their own personal needs. Our findings can help mitigate further science teacher attrition that may occur because of stresses created during the pandemic by informing teacher educators and schools about how to support teachers.

Hartley Banack Gerald Tembrevilla

Fresh Air: Glowing Conspirations Towards Scientific Fluency

Our work introduces fresh air as a metaphor gesturing towards unity and inclusion, particularly related to global scientific fluency. Parting from two recent independently conducted research projects that noticed teachers and students alike were emphatic in their passion to breathe fresh air, we followed a meta-analysis design, exploring the demand for fresh air as a "glow" calling educators and learners to move, act, and connect outside the intellectual boundaries of subject disciplines and the architectural boundaries of the classroom. We concluded by inviting educators and learners towards a transcendence that might return all of us to ourselves and the world through renewed learning possibilities and connections. In breathing fresh air into science education's discourses and curriculum, we offer the fresh air metaphor as a medium to inspire and support science conversations in the open world.

Roshni Bano Minjung Ryu

Framework for chemistry course redesign to support first generation college student success

First generation college (FGC) students form a sizable portion of the U.S. undergraduate body but are known to leave college at higher rates than their continuing generation peers. In particular, FGC students have higher DFWI rates in introductory chemistry, and these higher DFWI rates are correlated with leaving college. Thus our goal in this paper was to suggest, by drawing on a literature review, a framework to redesign courses to support FGC student success in chemistry. We found very few studies on interventions in chemistry education focused on improving the classroom experiences and learning of FGC students. Thus we synthesized our framework based on studies of interventions to improve the classroom experiences and learning of historically minoritized students in general. Our intervention framework comprises four main approaches: providing additional academic support, using constructivist instructional practices such as active learning, cultivating a more welcoming classroom culture, and reforming curricula to be more inclusive. We provide this framework as a tool for evaluation and planning for chemistry instructors working towards equity in their classrooms. We hypothesize that this framework is applicable to support FGC students; however this needs to be verified in future work.

Carmel Bar Bat-Shahar Dorfman

Biology Teachers' Knowledge Considerations and Pedagogical Goals When Designing Dataset Driven Instruction Units

Introducing authentic datasets to the science classroom may facilitate developing scientific practices and epistemic thinking. However, datasets are not commonly used in high school in general, and in a biological context in particular, and little is known about biology teachers' considerations when designing dataset driven units. We therefore strived to investigate what are high school biology teachers' pedagogical goals and knowledge considerations, when designing dataset driven instruction. A professional development workshop was developed and held. Forty teachers were asked to design dataset driven instruction units, and completed an open-ended questionnaire. Our analysis indicates that epistemic considerations were the most prominent in teachers' perceived benefits of teaching through authentic datasets. However, when actually designing their units, epistemic considerations were less pronounced relative to content and procedural knowledge considerations. Our findings suggest that teachers recognize the value of epistemic thinking for students' scientific literacy and see authentic datasets as a means to facilitate epistemic thinking and engage students in authentic practices of data analysis. Further efforts are required to assist teachers in designing instruction units, which better represent these goals. Future professional development courses may explicitly discuss the way epistemic considerations could be expressed in dataset driven instruction.

Ayelet Baram-Tsabari Lea Taragin-Zeller

"We think this way as a society!": Community-level Science Literacy among ultra-Orthodox Jews

Despite growing interest in community-level science literacy, most studies have focused on communities of interest or affinity who come together through particular science, environmental or health-related goals. Here we examine a pre-existing community - Haredi (ultra-Orthodox) Jews in Israel - with a particular history and politics vis-à-vis science, technology and medicine, which includes almost no science education for men. First, we show how Haredi cosmologies and culture come together to critique science as an epistemology while engaging with science as a technology. Then, we demonstrate how community-based medical experts serve as both science-related knowledge mediators and gatekeepers. Whereas Haredi Jews in Israel are constantly critiqued for their low levels of individual secular and science education, these community-based webs of knowledge seemingly position Haredi individuals with knowledge that surpasses the average 'secular' Israeli. This case study develops unique analytical tools in the growing field of community-level science literacy, while pushing forward conversations about self-ascribed experts, knowledge gatekeeping and the socio-political contexts of group critiques of science.

Tara Barnhart Miray Tekkumuru-Kisa

Pre-service Teachers Notice Student Thinking. Then What?

A growing body of work indicates the importance of noticing student thinking to enact responsive science instruction and the ability of pre-service teachers (PSTs) to attend to and interpret the substance

of students' disciplinary ideas. What is less clear is if our PSTs respond to students' ideas in ways that reflect these purposes. The purpose of this study is to examine what about student thinking PSTs attend to, and how PSTs plan to respond to student thinking. Our examination of a video analysis task completed by science and math PSTs from three different teacher education programs revealed that many of them attended to the substance of students' ideas. However, how they planned to work with students' ideas that they noticed varied. Our analysis revealed the moves that PSTs planned to use to respond to students' ideas that they noticed as well as their purposes for selecting these moves. Our findings invite teacher educators' attention to the need to move beyond simply helping PSTs learn to notice student thinking and move towards finding ways to support PSTs in working with students' ideas to support their sensemaking in science classrooms.

M. Elizabeth Barnes Hayley Dunlop

Religious Cultural Competence in Evolution Education and its Association with Changes in Student Acceptance of Evolution across the United States

Many people not only lack an understanding of evolutionary concepts but also resist accepting the theory of evolution as the best scientific explanation. Factors affecting the development of understanding and acceptance are diverse, including cognitive, affective, and contextual features. Religious identity and background are often negatively related to acceptance rates and are among the main factors for predicting whether people will accept or reject the theory of evolution. To contribute to this ongoing challenge that peoples' religious identity brings into evolution education, this related paper set combines four papers that focus on the interplay of religious identity with evolution acceptance. In the first paper, historical data were investigated to determine if acceptance patterns have changed over time based on students' religious affiliation. The second paper determined the influence of culturally competent practices on students' evolution acceptance outcomes. The authors of the third paper gathered evidence through in-depth interviews to better understand conceptions of religious people but who accept the theory of evolution. In the fourth and last paper, responses of self-identified creationists to often-used evolution acceptance measurements were collected to generate new validity evidence.

Selina L. Bartels

Utilizing lesson study to lay the foundation for preservice teachers to begin shaping elementary students' scientific literacy

This study examined how an integrated preservice elementary education program used lesson study to deepen the practice and planning of scientific literacy intentional teaching during a practicum experience with the science methods. It was found that although preservice teachers (PST) could plan and deliver integrated teaching in a micro teaching setting, when they entered the field this did not occur. Although the PST program was intentional in the delivery of content and field experience, the connections were not made in the field despite the lesson study format.

Kathryn M. Bateman Brandin Conrath

Managing disruptions and dilemmas in online geoscience instruction during the COVID-19 pandemic

The COVID-19 pandemic provided a natural experiment to study ways in which higher education faculty in the geosciences adapted their teaching to meet the needs of online learning. Using survey data collected in spring and fall 2020 and interview data in January 2021, we first elicited real-time information related to the disruptions to teaching, research, communication, and work-life balance in the early days of the transition to online learning as well as long term data as this transition evolved. Data analysis identifying dilemmas related to obstacles to quality online learning and supportive teaching resources. Faculty experienced disruptions to teaching, research, communication, and work-life balance universally across demographic categories, though non-tenure-track faculty reported increased disruption to teaching over the course of the study. Faculty expressed dilemmas in teaching online in new ways. The personal turmoil from COVID-19 impacted faculty's teaching, as well as novel challenges related to the online format such as weak internet connections and unannounced software updates. Faculty were supported in overcoming disruptions and dilemmas when provided time and learning opportunities. Time could be acquired through reteaching the same course or having fewer students in a course. Professional learning occurred in both formal and informal channels.

Gillian U Bayne

Centering Black Scientists' Lived Experiences : A Context for Culturally and Linguistically Embedded Science

The HistoryMakers' Digital Archive, "The Nation's Largest African American Video Oral History Collection" and one of its specialized categories, the ScienceMakers, were used to explore inroads into pedagogical practices that can align with the lived experiences of youth today – especially those who have been estranged from science and marginalized by systemic oppression. The research offers an examination of the intersection of professional and personal identities; expectations, persistence and enhancement of self-efficacy; personal and family oral and written histories; and moments that reveal inspiration and motivation. ScienceMakers' interviews were analyzed qualitatively by locating patterns along these inclusive dimensions from archival transcripts. Factors identified through the themes that play a role in strengthening interest and success in science will be shared during the presentation. Authentic curricular tools embedding the details of ScienceMakers' experiences were created as new ways to learn how to plan for and enact culturally and linguistically embedded science pedagogy – pedagogy that deeply incorporates the individual and collective lifeworlds, lived experiences, community wisdom, and oral and written histories of diverse People and Youth of Color. The pedagogy speaks directly about and to those who have endured deficit models of instruction, and have been victims of racial and ethnic stereotypes.

Dürdane Dury Bayram-Jacobs Ineke Henze

Formative Assessment in Socio-scientific Issues-based Science Lessons: How Teachers do this

Teaching Socio-scientific Issues (SSI) promotes student skills (e.g. reasoning, assessing reliability of information sources, etc.). Although, in practice, science teachers often integrate SSI in their lessons, teaching SSI systematically is difficult. Teachers experience reluctance to assess SSI-related skills and provide feedback. There is also a recognized lack of effective assessment strategies for SSI-related skills. Summative tests are not suitable for providing insight into these skills. Instead, formative assessment (FA) offers insight into developing students' skills and provides tools for feedback. In this study, three teachers designed and enacted SSI-lessons, including FA tools and strategies. The study aims to investigate which FA tools teachers find helpful, which barriers they experience, and what they want to change next time. The data were collected via semi-structured interviews before and after the lessons. The lesson plans provided additional data. Qualitative data analysis revealed that all teachers used 'Group discussion', 'Walking around the class', and 'Whole class discussion'. The teachers found it challenging making SSI skills visible. However, the FA tools & strategies used, they think that all worked well. The most mentioned barriers were 'Extra time is needed for preparation', 'Guiding students is difficult'. Next time, they want to 'Plan more time for feedback'.

Christina L. Baze MarÃa GonzÃjlez-Howard

Students' Considerations of Epistemic Criteria and Subsequent Tensions in Mixed-gender Engineering Groups

Science, technology, engineering, and mathematics (STEM) education has shifted in the past decade toward practice-based instruction, emphasizing meaningful engagement in science and engineering practices (SEPs). However, there is a lack of research in engineering education "focused on how people access and make use of science knowledge and engineering practices to solve the kinds of problems identified in the Framework and NGSS. We know far too little today about how people learn to use science and engineering in practice to support key elements of the vision of the Framework" (Penuel, 2016, p. 96). Furthermore, girls and women have historically been excluded from engineering and continue to be underrepresented (Geisinger & Raj Raman, 2013; Malicky, 2003; Slaton, 2015). This problem presents a need for research to develop a better understanding of the epistemic practices and criteria female students use when designing solutions in social groups. In this study, student engagement is framed through epistemologies in practice (Berland et al., 2016) to describe meaningful use for both knowledge-building and discipline-based (engineering) goals. Findings from this case study show that tensions within a middle school group inhibited meaningful participation for students, especially girls.

Kelsey Beeghly

Impact of Inquiry Lesson Experiences on Development of Preservice Elementary Teachers' Effective Science Teaching Beliefs

A pilot study was conducted at a large southeastern university to examine the impact of multiple inquiry lesson experiences on preservice elementary teachers' beliefs about effective science teaching. As part of an elementary science methods course, three inquiry-based lessons were modeled by the instructor,

students in pairs designed and executed an inquiry lesson to their peers as if they were elementary students, and students utilized feedback from the group lesson plan process to develop a final lesson plan individually. All lessons involved reflection and instructor and peer feedback, and were developed using a template structured around the 5E learning cycle (Bybee, 2009). A mixed method analysis using pre and post course responses to the Teacher Beliefs about Effective Science Teaching (T-BEST) questionnaire (Smith et al., 2014) revealed significant increases toward reform-aligned beliefs for 8 of the 21 items spanning the three factors measured by the survey, "all hands-on all the time", confirmatory science instruction, and learning-theory-aligned science instruction. Students' reflection papers from the end of the course were qualitatively analyzed for themes related to what students believed to be the most important features of effective science instruction. Findings show improved science teaching beliefs, as well as increased confidence for teaching science among the preservice elementary teachers.

Adam Bell Jeff Chandler

Community-based Research as Pedagogy for Strength-based Teacher Education

This related paper set responds to calls for re-imagining disciplinary learning in science (Warren et al., 2020) and "broadening participation" in STEM (NSF Includes, 2019). Specifically, the papers in this session will explore practices such as anti-deficit noticing as ways to support equitable science teaching and learning. Deficit ideologies can lead researchers and educators to blame students for perceived deficiencies in school rather than attending to the social structures that limit students' opportunities for learning (Peck, 2020; Philip, 2011). Anti-deficit noticing (Louie et al., 2021) is a teaching practice that explicitly challenges these deficit ideologies by (1) identifying deficit frames that limit students' opportunities for learning and (2) shifting toward anti-deficit frames that empower minoritized students. While anti-deficit noticing is becoming increasingly prominent in math education (Louie et al., 2021), less is known about how this practice can be supported in science education. In response, this session will offer an illustrative example of anti-deficit noticing in a secondary science classroom, and it will explore anti-deficit approaches to preservice teacher education and in-service teacher professional development.

Philip L. Bell Abby Rhinehart

A Landscape Survey Analysis of the Potential for Equity-focused Science Education across the PK-12 Education System

There is an increasing recognition in the role science has to play in issues of in/equity with respect to opportunities to authentically engage in civic activity from local to global scales. In systems of science education, societal power dynamics and resulting inequities interweave both the challenges of the scientific community and histories of inequity within educational systems more broadly. In this related paper set, we explore findings from a mature research-practice partnership, the Equitable Science Education Research Practice Partnership (ESERPP; pseudonym) project, designed to bring together partners from educational research and practice to promote equity and coherence in science education.

Throughout the project, we engage in design-based implementation research to support those engaged in the work of bringing equitable models of teaching and learning into science learning contexts that reflect and extend the vision of equitable teaching and learning presented in A Framework for K-12 Science Education. In this related paper set, we will share learning in four papers across the ESERPP Project's shared goals to align curriculum, instruction, and assessment through a focus on professional learning through open education resource (OER) development, strategic leadership development, and social organizing across a network of networks.

Ana I. Benavides Lahnstein Heidi L. Ballard

YOUTH ENVIRONMENTAL SCIENCE LEARNING AND AGENCY: A UNIFYING LENS ACROSS COMMUNITY AND CITIZEN SCIENCE SETTINGS

This study addresses an existing gap in our understanding of how participation in environmental Community and Citizen Science (CCS) projects may impact young volunteers' environmental science learning across a wide variety of settings. We examined youth learning across four settings which we represented as cases: 5 short-term field-based events (BioBlitzes), 3 longer-term field-based monitoring programs, fully online projects (Zooniverse), and a hybrid format that combines participation in the field and online spaces (iNaturalist). This multiple-case study uses the Environmental Science Agency framework to interpret learning evidence of 33 young CCS volunteers (aged 10-13 years) in post-participation surveys, semi-structured interviews, and in ethnographic field notes for the field-based participants. Across the cases, we found particular features of the CCS projects and the scientific framings that may have encouraged aspects of ESA. Design features such as access to new knowledge, training, and scientific tools provided by the CCS projects encouraged youth to learn rich and varied understandings of disciplinary content, scientific skills and practices. An increased sense of confidence and competence in youth around the scientific practices of the projects were stimulated by scientific framing of CSS and ongoing participation. Overall, these aspects also supported small manifestations of youth agency with science.

John Lawrence Bencze Dave Del Gobbo

Students' Material-Semiotic Alliances After Power-focused Application-based Learning

Humanity is facing myriad 'wicked' problems — including those linked to climate, surveillance systems, manufactured foods, habitats and related species diversities — associated with capitalism-influenced fields of science and technology. Assuming capitalist manipulation of public knowledge and subjectivities and learners' diverse abilities, cultural and social capital, etc., the five papers in this Related Paper set provide theoretical and empirically-based evaluations of a constructivism-informed pegagogical schema (ReActions) that prioritizes direct teacher instruction of often difficult-to-discover conceptions in relationships among science and technology and societies and environments and education encouraging and enabling students to independently implement sociopolitical actions to overcome harms like those above of their concern. The five papers appear to support Unity and Inclusion for Global Scientific Literacy through qualitative action research to apply and evaluate the ReActions schema in multiple

educational contexts (primary, secondary & tertiary), drawing from Science & Technology Studies [STS]) and the arts to understand possible alignments among numerous 'actants' within a growing dispositif (i.e., purposeful machine-like actor-networks) that may promote ecojustice outcomes, like: community-centred (vs. individualistic) goals; ecocentric (vs. anthropocentric) worldviews; tempered (vs. continuous) change; and, intrinsic (vs. exchange) values. STS conceptions apparently aiding this work include: sociotechnical imaginaries; dispositifs; phenomena-semiotic relationships; (de-)punctualization; and, governmentality.

Amanda Benedict-Chambers Carrie-Anne Sherwood

Preservice Elementary Teachers Noticing Features of Classroom Instruction that Support Equitable Sensemaking

Contemporary reforms in science education emphasize the importance of supporting equitable sensemaking through privileging ways of knowing science that honors students' ideas, experiences, and community resources. Recognizing the challenge of learning to do this work, this paper set investigates how elementary preservice teachers (PSTs) can learn the knowledge and practices that facilitate more equitable learning opportunities. Paper 1 examines PSTs' engagement in equitable sensemaking of local phenomena as learners and how the PSTs discuss using local resources to engage students in making sense of local problems. Paper 2 focuses on PSTs' subject matter knowledge required for noticing and using students' ideas in equitable ways. Paper 3 examines how PSTs' thinking about how to leverage students' ideas and resources change over the course of a semester. Paper 4 investigates how PSTs noticed opportunities for promoting equitable sensemaking within their enacted lesson plans. By focusing on different elements involved in learning to support equitable sensemaking, this paper set illuminates the complexity of this work, and thus, the multiple dimensions that require consideration in elementary education. The findings have implications for teacher educators and curriculum developers working to prepare teachers to develop the practices and dispositions that move toward more equitable teaching.

Matthew D. Bennett Valerie Valdez

Learning to Teach During a Pandemic: Preservice Secondary Science and Mathematics Teachers' Use of Resources

Supporting preservice teachers to enable a successful entry into teaching has been a key goal of teacher education programs for several decades. However, the COVID-19 pandemic created contextual changes that impacted how preservice teachers both learned to teach and began developing their teaching practice. In this study, we considered how preservice secondary science and mathematics teachers used resources while learning to teach during the 2020-21 school year, and how shifting contexts for learning to teach impacted the resources these preservice teachers used. We qualitatively analyzed interviews from 14 participants conducted at four points during the year. We found that face-to-face tools, knowledge-embedded tools, and technology tools were the most common resources used, but varied as teaching contexts changed from remote to hybrid instruction. While the pandemic brought technology

to the forefront of education, technology tools were not uniformly considered to be helpful resources, and sometimes inhibited teachers' abilities to elicit student ideas to adapt instruction. We argue that understanding the resources used by preservice teachers during a tumultuous year can provide teacher educators with a firmer sense of how to adapt the resources they provide to preservice teachers, whose contexts for teaching and learning are neither uniform nor predictable.

Tess Bernhard Amy Guillotte

Variable Take-up of Professional Development: How Activity Systems Influence Science Teachers' Enactment of Project-Based Learning

This comparative case study of three high school science teachers in a project-based learning (PBL) professional development (PD) program uses cultural-historical activity theory to investigate teachers' take-up of PD tools and the ways that different norms, communities, and goals at specific schools influence enactment of PBL. Findings suggest that 1) robust conceptual frameworks of ambitious science instruction and aligned tools for teacher reflection; 2) access to technology tools; 3) educator collaboration within a school community are all supportive of PBL instruction. Our findings indicate that variation in teachers' adaptations of PD tools to their own classroom and school context may be influenced by the resources and structures available in their schools. This has implications for equitable and ambitious science instruction and for science teacher educators, PD designers, and administrators to attend to not only individual teachers, but to the community support, collaboration, and resources available to teachers as they adapt PD tools and learnings to their own school context.

Arne Bewersdorff Armin Baur

Investigating the Effectiveness of an Innovative Professional Development Program for Inquiry-based Secondary Science Education

Professional development (PD) in science education should be as effective as possible, i.e. it should develop teachers' professional knowledge, beliefs, teaching practice and ultimately student achievement. The proposed study investigates in how far intensified-collaboration during PD programs can deliver on this claim. One study of a larger project used video analysis to determine in how far two formats of a PD program on inquiry based-learning (IBL) through experimentation elicited changes in teaching practice. Six teachers attended a format with intensified-collaboration, nine a more individual format. Three different instruments were used in these analyses: 1. A category system to track the time on task for each subprocess of experimentation, 2. A rating scheme for evaluating the degree of openness during an experiment and, 3. an observation protocol for in-depth analyses. Results indicate that there is some benefit from explicitly strengthening participants' active involvement. In the intensified collaboration format teachers succeed significantly more in opening their students' experimentation processes over time. In both PD formats there are significant changes in the lesson time devoted to teaching each of the subprocesses: time for question formation, hypothesis generation and planning increased, while time allotted to execution and evaluation decreased.

Petra Bezeljak Anna-Lena Neurohr

Longitudinal effects of nature experiences on middle school students' environmental attitudes, interest and knowledge

Studies demonstrated that direct nature experiences have a positive influence on preadolescences' proenvironmental behavior. However, most studies conducted in the school context describe only effects of short-term interventions. This study explored the possible impact of a 3-year teaching intervention with direct nature experience on middle school students. We investigated 1) how environmental attitudes, interests and knowledge possibly progress, 2) whether there is a correlation between environmental knowledge, interests and attitudes and if yes, how they influence each other and 3) whether personal background, such as parents' education and cultural background impact the development of environmental attitudes, interests and progress of environmental knowledge. The intervention study with 4 data collection points (T0-T3) was conducted with 370 middle school students starting grade 6. The questionnaire included items from known scales, i. e. the "Major Environmental Values-2-Model", "Inclusion of Nature in One Self (INS)", and "Children's Environmental Attitudes Knowledge Scale (CHEAKS)". Results of the pre-test (T0) show positive attitudes toward nature but lack of general environmental knowledge. Results of T1 already indicates significant changes, depending on several factors. Data (T0-T2) will be presented in detail at the NARST Conference and discussed in reference to environmental education programs.

Haider Ali Bhatti Perman Gochyyev

Improving Self-Reported Measures of 21st Century Skills in an Interdisciplinary Undergraduate STEM Course

To advance STEM education beyond content-based memorization and towards the development of skills-based practices applicable to the careers of tomorrow, the present paper describes how an interdisciplinary STEM course called Bioinspired Design improved self-reported measures of 21st Century Skills in undergraduate students. In this course, open to all majors and all years, students worked in interdisciplinary teams to translate authentic scientific discoveries from primary literature into societally impactful bioinspired designs. We hypothesized that students would grow in 21st Century Skills such as Scientific Discovery and the Translation Process, Interdisciplinary Thinking, and Interdisciplinary Collaboration as a result of completing the course and engaging in course activities. We assessed our hypothesis through a survey-based methodology analyzed using item response theory. We considered students' growth as aligned with our construct map that included five levels of ascending competence related to 21st Century Skills (Required, Technical, Participant, Active, Leader). A pre/post comparison of students' self-reported 21st Century Skills showed growth in all survey items, equating to 0.89 standard deviations of growth in student ability resulting from completing the Bioinspired Design course. The improvement translates to a one "step" increase across all items on the Likert scale (i.e., "Agree" to "Strongly agree").

Tom Bielik Moritz Krell

Using concept maps to evaluate preservice biology teachers' conceptualization of Covid-19 as a complex phenomenon

The science education community acknowledges the importance of integrating learning about complex systems and adopting a system thinking approach as part of the effort to prepare scientifically literate citizens. However, accumulating research in the past years has clearly shown that teachers and students alike face various challenges engaging in aspects of system thinking. One of the prominent challenges includes the difficulty of addressing underlying mechanisms that account for a system's behavior. In this paper set, an international effort is made to present different tools and strategies that can serve to elicit some of the underlying mechanistic reasoning teachers and students use to make sense of complex systems. We show how system dynamics models, agent-based models, and concept maps can be used to elicit students' mechanistic reasoning and support it. Our collaborative work provides an opportunity to learn about different tools and the affordances they provide, both for characterizing mechanistic reasoning in the context of complex systems, and supporting teachers and students in making sense of complex phenomena using system thinking aspects.

Patricia S. Bills Imogen Herrick

Elementary teachers' understandings of student cognitive engagement in science through witnessing models of classroom instruction

While the Next Generation Science Standards has defined for our field the importance of student engagement of science practice and a shift from knowing about content to figuring out phenomena, the field has not yet come to a clear understanding of what engagement entails for our youngest learners, and how teachers achieve such engagement. Our research examines an elementary science teacher professional development program that uses live teaching demonstrations in elementary classrooms in real-time to show student engagement in various NGSS-aligned lessons. We analyzed two years of interview and classroom observation data of seven case study teachers who participated in the program. We then apply a cognitive engagement framework called ICAP (Chi & Wylie, 2014) to describe the shifts that teachers make over time in their understanding of student cognitive engagement in science. Results indicate that some shifts were made from passive, to active, to more constructive engagement, but that further research is necessary to determine how teachers move to integrative engagement, the most cognitively engaged form. This paper contributes to the literature a new way of applying the ICAP framework, as well as insight about teacher understanding of student engagement in science.

Maia K. Binding Lauren Brodsky

Designing for Engineering: A Model for Integrating Engineering and Science NGSS Middle School Benchmark Assessments This study focuses on a project designed to develop a comprehensive suite of curriculum-neutral benchmark assessments for the middle school NGSS performance expectations, looking in particular at the approach used to address the assessment of the Engineering Design (ETS) Performance Expectations (PEs). The project team developed an approach to assessing the ETS PEs where the ETS PE dimensions are layered onto an existing science PE item set, as a method for integrating science content with the engineering content within the assessment. This study aims to answer the following question: Does the project approach of integrating the NGSS ETS PEs with science PEs lead to the design of items that elicit 3D student performances aligned to both PEs? Findings from three evidence sources are analyzed and discussed: 1) multi-curriculum review, 2) external expert review, 3) external testing. Results indicate that the project design and development approach results in engineering assessment items that are curriculum neutral and elicit 3D responses in line with both the ETS and science PEs. The resulting items are proposed for use in a broad range of classrooms, regardless of curriculum choice, to assess authentic student understanding of the three dimensions of the ETS PEs.

Mary Binzley Paul Hutchison

Instructor Impact on the Equity of Collaborative Small Groups in a Science Class

In this paper, we seek to better understand the impact instructors can have on inequity within collaborative small groups. We do this by analyzing the practices of one experienced instructor in a preorientation program designed for STEM-interested students from underrepresented groups. We analyzed 37.5 hours of video data of four different collaborative small groups to identify relevant instructor-small group interactions. The paper includes qualitative case studies of four insightful/illustrative interactions. We observed that the instructor's routines for interacting with small groups are primarily aimed at supporting a group's learning outcomes, and he excelled at supporting learning outcomes because he used strategies specifically aimed at assessing and advancing a group's progress toward learning outcomes. However, he did not have similar assessments for understanding group inequity. When he did have insight into group inequity, the instructor responded to support greater equity with reasonable effectiveness. This project identifies assessment as a key issue for instructors responding to support greater equity within collaborative small groups and suggests further research should explore how science instructors can elicit and attend to assessment information related to equity.

Marina Regina Birkenstock David S. Di Fuccia

The Interconnectedness of Chemical contents – a Challenge for Teacher Training

The aim of this study is to support chemistry teacher students to better interconnect chemical contents during their studies. This is formally focused on university level and thereby referred to university course contents as we assume that at this point students are missing obvious and relevant interconnections among chemical sub-disciplines. This might cause many teachers-to-be to not realize and implement interconnected content knowledge in their later profession as a chemistry teacher in an appropriate way. With the help of advanced organizers, it is envisaged to give future teachers a stable and

expansible framework of knowledge along their way so that the first stage of training simultaneously impacts the fundamentals of teacher's professional knowledge, especially content knowledge, in a more qualified and more interconnected manner.

Estelle Blanquet Eric Picholle

Massive Dependence of Science students' answers about Relativity upon the Formulation of the question

The purpose of this study is to determine to what extend students may defend notoriously obsolete positions, whether or not they're familiar with the current scientific consensus; and whether specific formulations might trigger such epistemological skidding. Due to its deep embedment in our present popular culture, the Copernican paradigm appears at first glance associated to a particularly strong paradigmatic pressure. The study thus focus on the reception of scientific propositions more or less explicitly related to Copernican heliocentrism, as opposed to the more modern relativist approach. Results confirm that yielding to the paradigmatic pressure is a very common cognitive process. An overwhelming proportion of science students, as well as of future primary school teachers, fall back into an obsolete, pre-Galilean thinking. This process can be either increased or avoided by specifically designed formulations. For instance, it can be triggered by direct references to a culturally 'hot' issue, such as the relative movement of Earth and Sun in an ostensibly Copernican culture.

Tom Bleckmann Gunnar Friege

Analysis of Concept Maps for the use in Formative Assessment: Can Machine Learning help?

Formative assessment does not only mean an improvement of the teaching-learning process, but also that a large amount of different data has to be collected, evaluated and analyzed for each individual learning in order to be usable for further steps in the classroom. It is usually an additional workload for the teacher to the already stressful school day. This is also evident in the use and qualitative evaluation of concept maps. With a long evaluation time, it is impossible to use concept maps for a high-quality formative assessment in the classroom. We apply Natural Language Processing techniques for the qualitative evaluation of the individual propositions so that a formative assessment with concept maps in a class is possible in a timely manner. Through the machine learning approach, a first step towards an automatic high-quality formative assessment with concept maps could be achieved. This not only enables better individual support for each learner, but also provides time savings for teachers.

Phillip A. Boda Emily Harrison

Supporting middle school students to integrate graph data with physical science content

Concepts such as energy and energy transfer are important for disciplinary learning across science, technology, engineering, and mathematics (STEM). To help students develop more sophisticated explanations of concepts that require systems-thinking, we report on instruction that supported over
400 middle school students to integrate graph data with physical science content across a two-year period. The design of the technology-enhanced curriculum and summative assessment items utilized the Knowledge Integration (KI) framework. This research-practice-partnership led by two 8th grade teachers adapted these units in collaboration with university partners. A combination of virtual experimentation using graphs and simulations (on an online computer-based platform) and physical model building of 'self-propelled scooters' helped students to collaboratively integrate their knowledge into cohesive, systemic thinking around energy. Analyzed with ANCOVA, linear regression, and non-parametric statistics, the results suggest that students who start with fragmented knowledge of energy before the unit benefited most from studying friction to link graph data and energy concepts. Also, simulation questions designed to support systems-thinking helped students to explain and represent energy and energy transfer in more sophisticated and quantifiable ways, assessed through students' small-group concept-maps pre-/post-unit. This research suggests implications for designing questions for systems-thinking and teacher-led redesign within research-practice-partnerships.

Lisa A. Borgerding Bridget K. Mulvey

College Students' Epistemological Beliefs about Medical Science and Trust in Science and Scientists during COVID-19

Individuals and community have had to make health-related decisions about COVID-19 with limited and sometimes changing information. Their trust in science and scientists has informed the extent to which they heed public health recommendations during the pandemic. Importantly, one's beliefs about the nature of medical knowledge may be predictive of one's trust in science and scientists. This multiple regression study examined the contribution of epistemological beliefs about the field of medical science and several demographic variables on college students' Trust in Science and Scientists. The statistical analysis indicates that both the nature of knowing and nature of knowledge as well as one's year in college are predictive of Trust in Science and Scientists. Implications for enhancing epistemological sophistication and consequently Trust and future research are discussed.

Lisa A. Borgerding Jennifer Heisler

Ohio Secondary Science Teachers' Climate Change Instruction

Anthropogenic climate change is an urgent issue, and climate change education is essential for curbing the most devastating impending impacts of climate change. This study uses a sequential explanatory mixed methods design to explore Ohio secondary teachers teach about climate change in terms of framing, goals, identities, topics, controversy approaches, and teaching methods. The survey sample consisted of 86 Ohio secondary science teachers, and 26 of these teachers were interviewed following survey completion. The main findings are that teachers primarily framed climate change as a current social problem with human causes operating at a global scale. Teachers prioritized relevance, critical thinking, and science content understanding goals over pro-environmental attitudes and behaviors. In terms of identities, teachers embraced student-interest engager and content-first educator identities more than passionate environmentalist and civic skills promoter identities. Many teachers used controversy-avoidance approaches when teaching climate change and seldom employed research-supported teaching methods such as local investigations of climate change, interactions with local

scientists, or climate science-specific technologies. Implications for science teacher education are discussed.

Florian Böschl Tina Vo

Empirically Grounding a Learning Performances Framework for K-5 Students' Modeling Competency Using Evidence-Centered Design

At the forefront of educational reform efforts (GDSU, 2013; NGSS, 2013; OECD, 2017) is an emphasis on students' engagement in scientific practices, which includes scientific modeling. Understanding how models act as representations and tools can supports students' sense-making about system interaction by explicitly linking components, mechanisms, and sequences within complex natural phenomena, (e.g. the water cycle) which are covered across multiple grades, including elementary. Within elementary science classrooms, learners should be afforded opportunities to generate, explain, compare, and evaluate models and be engaged with the more epistemological features of scientific modeling. To better support and foster elementary students' modeling competency, learning performances (Krajcik et al., 2007) integrating scientific modeling with disciplinary concepts can be employed to articulate cognitive tasks and related expectations to be measured. To that end, we are engaged in a multi-phase exploratory research project focused on developing and investigating a learning performances framework focused on elementary students' modeling competency about water. Evidence-Centered Design (Mislevy et al., 2017) is used to guide and inform the development of performance tasks embedded in an interview protocol to empirically ground and refine the framework. Here, we report findings from the current iteration cycle, drawing on interview data and tiered student work.

Madison Botch Amy R. Pallant

Ambitious Science Teaching as a way of integrating place-based and systems-literacy learning

The goals of this conceptual paper (theoretical proposal) are to address the existing tension in geoscience education between systems-level and place-based pedagogical perspectives, and to propose Ambitious Science Teaching (AST) (Windschitl, Thompson, & Braaten, 2018) as a mediating framework. Through AST, both pedagogical perspectives can interact in a mutually-inclusive way to advance student sensemaking. The analysis in this proposal presents the story of one middle school science classroom to demonstrate interactions of these pedagogies in the implementation of AST practices. The story of two co-teachers' implementation of AST practices is described to identify theoretical interactions between systems-literacy and place-based pedagogical perspectives. These teachers' knowledge and experience with AST created space for the integration of systems-literacy and place-based pedagogies within their geoscience curriculum. This classroom example is not presented in the form of a traditional empirical analysis, but rather as a means to support the explanation of the indicated theoretical interactions.

Janne-Marie Bothor David S. Di Fuccia

Pre-Service Chemistry Teacher's Beliefs regarding the use of Experiments and Nature of Science

Experiments are often used in chemistry lessons to reproduce and illustrate existing scientific findings. Experiments in which learners get to know the process of Scientific Inquiry (SI) and gain a better understanding of the origin of knowledge also contribute to the promotion of Nature of Science (NoS). Nevertheless, the function of this process as an epistemological tool (Nature of Scientific Inquiry, NoSI) is rarely addressed. Our case study was conducted in a learning environment with the aim of imparting knowledge about scientific inquiry by analyzing chemical experiments on a meta-level (NoSI). In interviews with 7 participants, the beliefs regarding the use of experiments in chemistry lessons were captured. In addition, the participants created a concept map in which they were asked to link their understanding of NoS with their lab work and describe their approach with loud thinking. The results of the interviews show that the participants' beliefs regarding the use of experiments mainly regard experiments as an instrument for knowledge reproduction and also as an instrument for gaining knowledge and only rarely as an instrument for conveying NoS/NoSI. The concept maps show that the aspects of NoS are mainly assigned to the phase of evaluation and interpretation.

Jonathan R Bowers Gail Richmond

Native Animals, Native Knowledge? An analysis of zoo portrayal of Indigenous Cultures

Contemporary zoos often include exhibits on animals that are intricately linked to indigenous cultures (such as the American Bison and the Lakota People). Given these close relationships it is difficult to accurately represent the ecological and conservation history of an animal without referencing associated native cultures. Additionally, while contemporary zoos primarily focus on animal conservation, many zoos have a shameful past of upholding colonialist narratives. Zoos also have great power to educate the public. Therefore it is important for them to include indigenous knowledge (IK) and traditional ecological knowledge (TEK) in their informational signs and exhibit designs to address both their colonialist legacies and key conservation narratives that would otherwise be ignored. To investigate how zoos incorporate or ignore indigenous perspectives and TEK in their exhibits on native animals, we analyzed zoo websites, YouTube walkthroughs of zoo exhibits, and interviewed zoo staff. Through the triangulation of these data sources, we were able to contrast how different zoos approached IK and TEK in their exhibits on native animals. Overall, we found a stark contrast between how one zoo centered their exhibits on a White Settler perspective, while another zoo included IK and TEK in its approach to conservation education.

Jon Boxerman Sharon Nelson-Barber

How to Broaden Participation in STEM by Indigenous Islanders

An individual's identity and sense of belonging to STEM predict intentions to persist in STEM higher education and pursue a STEM career. A failure to integrate local ecological knowledge with western STEM literacy has reduced opportunities for learners to "see themselves" in STEM courses and careers. The absence of island students from the STEM enterprise limits the range of cultural perspectives that are available to shape and direct the future of STEM. This five-year multi-institution research project is examining how Indigenous islanders maintain identity and sense of belonging to their heritage culture and to STEM while carrying out scientific research through community-based and culture-based STEM programs and activities. The project connects hundreds of students from six cohorts of Indigenous and diasporic students, from three island contexts—Guam, Puerto Rico and the U.S. Virgin Islands. These programs are designed and implemented by university staff and local community members to engage students in STEM learning and development opportunities. We are studying the programs with culturally responsive methods including individual interviews, participant observations, and surveys. We are finding broadening participation in STEM is being fostered through apprenticeships in research labs, collaborations with peers, regular cohort building activities, and intergenerational mentoring activities.

Amir Bralin Thomas Chapman

Engineering Design in Introductory Physics: Undergraduate Students' and Graduate Teaching Assistants' Perceptions

Skills needed to solve complex problems are critical for scientists and engineers in the 21st century workforce. Research suggests that engineering design (ED) experiences have the potential to bring value to a science course. We explore undergraduate students' and graduate teaching assistants' (GTAs) perceptions of an ED challenge to design a simplified Martian lander in the laboratory component of an introductory physics course for engineers and scientists. Results suggest that while most students were able to make connections to other classes and their majors, and reported using metacognitive monitoring and control strategies during the design project. However, student perceptions of the workload limited their interest. Efficacy of any educational intervention depends upon the educators' knowledge of pedagogy, goals, strategies, and students' learning. We conducted a focus group interview with the GTAs about their impressions of the unit. Responses indicated a spectrum of views regarding the perceived value of the design challenge, its role in physics labs, and the GTAs lack of experience with ED. GTAs expressed concern that the ill-structured nature of the challenge left students and some GTAs unclear about the expectations for success. We discuss implications for implementation of ED experiences in introductory college science courses.

Denise M. Bressler Shane Tutwiler

"What if we explore..." Using Mountain Rescue to Promote Engaged Learning and Collaboration

According to the Committee on STEM Education, K-12 science students need access to learning experiences that are collaborative and engaging. To fill that void, we need to develop activities that stimulate engaged learning and scaffold effective collaboration. K-12 teacher candidates see value in utilizing games for this purpose. Specifically, tabletop science games can help teachers engage students in science learning and scaffold collaboration. For this study, we designed a collaborative, STEM-themed card game called Mountain Rescue and explored its capacity to promote engaged learning and collaboration. Designed for grades 5-8, the game takes approximately 30-minutes. Four groups of STEM campers (n=14) in a suburban Mid-Atlantic region played Mountain Rescue. During gameplay, players embodied unique STEM roles. They collaborated to solve challenges related to electricity, physics, chemistry, and engineering design. During gameplay, discourse was audio-recorded. Immediately after gameplay, self-report survey data was collected to assess flow and perceptions of collaborative learning. Findings demonstrated that students had a flow-like experience and felt positively about the game's

value for collaborative learning. Utterances demonstrating active engagement and constructive thinking became more group-focused over time. This study contributes to science education by demonstrating potential benefits of a well-designed, low-tech, science learning environment.

Katie L Brkich Alejandro J. Gallard

Social Covenants as Contextual Mitigating Factors (CMFs)

In this paper, we develop a conceptual framework to analyze the socio-historical-political conditions contributing to the development, construction, and either adoption or rejection of science education standards. We use the notion of covenants (Elazar, 1980) as a conceptual lens to examine the NGSS in teasing out the ways in which competing visions for science education can exist simultaneously within the same contexts. We argue that limit-situations found as contextual mitigating factors (CMFs) (Authors, 2018) manifest at the local, state, and national levels, and influence the enactment of science education reform movements as embodied within science standards. Limit-situations are sociocultural obstacles that limit the agentic actions of individuals (Freiere, 2014). We consequently argue that the covenants of science education create a series of overlapping mitigating-circles which lead either to the acceptance or to the rejection of these proposed science education reforms.

Alison Brockhouse Maia Elkana

Factors Associated with K-5 Science Teaching Time

The shift to NGSS teaching necessitates science as a core part of elementary school learning. However, science is often deprioritized and time spent on science continues to decrease. This study, in the context of a research-practice partnership, uses the Design-Based Implementation Research framework to examine time spent in elementary science, factors associated with time spent, and the impact on teacher perceptions on time allocation. Researchers gathered data through analysis of a large scale, biannual survey to educators involved in the partnership. Findings suggest that although few elementary teachers spent the recommended time on science, the most time was spent in upper elementary, especially fifth grade, where high-stakes state science tests occur. Teacher perception of science time had a significant association with the amount of time spent teaching science across grade bands, while district racial majority, free and reduced lunch, and teacher control was not significant. Qualitative coding of open-ended responses found district expectations and the focus on math and ELA as the most important factors influencing the amount of time spent on science instruction. Understanding factors associated with decisions about instructional time can support creation of targeted interventions to better support elementary teachers to spend more time teaching science.

Michelle N Brown

Reconsidering Touch in an Elementary Science Sensemaking Space

This paper considers how centering touch in a science sensemaking spaces helps researchers and teachers interrogate deficit perspectives of emergent bilingual Hispanic/Latino students, as well as the

school norms of being still. Through an ethnographic case study, I highlight how a 2nd grade elementary teacher and I move toward more expansive reflections and practices that center touch in science sensemaking over the course of three years. I use critical theoretical frames that center critical consciousness, disciplinarity, and Critical Race Theory. Along with video, interview, and field note data, I share three vignettes which show the tensions and expansions of touch over time. Initially the teacher vacillates between reinforcing school norms of staying still and centering touch through science sensemaking. Over time, the teacher and I move toward more critical reflection through Video Cued Ethnography, affording interrogation of deficit perspectives of touch. A third vignette highlights touch and cognition, influencing subsequent teacher-researcher collaboration to further leverage touch in science sensemaking.

Jeanne L Brunner Ryan Summers

How Teachers Used the Covid-19 Pandemic to Teach How Science Works

Since March 2020, the Covid-19 pandemic has provided the opportunity for the public to experience science-in-the-making in a very personal and relevant way. The changing information about the pandemic and vaccines illustrate how science is tentative and scientific knowledge changes as new information is developed. In this proposal, we present results from a survey of K-12 science teachers in which we asked if, and if so how, they included topics related to Covid-19 in their science instruction; their views of the importance of teaching about how science works; and their understanding of the tentative nature of science. Although most teachers addressed Covid-19 in some manner in their science teaching, very few used it to teach how science works. Additionally, most of the teachers in our sample held inconsistent views of the tentative nature of science like Covid-19, rather than the established science that is typically taught in K-12 schools. We conclude by acknowledging the difficulty of teaching a topic like Covid-19 that may increase stress or anxiety in students, as well as recommendations for supporting teachers who want to include these topics in their instruction.

Zoe E. Buck Bracey Lindsey Mohan

Addressing Tensions Inherent in Using Student Surveys to Make Equitable Decisions about Phenomenon Selection

In this proposal for a related paper set, the authors of the individual papers are science education researchers who are engaged in the development of instructional materials designed for broad use across the U.S. The premise of the project is that science education researchers bring a valuable set of perspectives, knowledge, and skills to this work. At the same time, the process of developing instructional materials for widespread use across the diverse school settings that are found in the U.S. has called for the participating researchers to develop new perspectives, knowledge, and skills. Throughout this paper set, we explore the challenges of bringing researcher perspectives and research-based approaches to the design of instructional materials for broad use. We do so through case studies in which we describe how we have been able to apply theory, findings from prior research, and research methods to achieve the goals of the project. We also describe how the challenges of the project have required us to go beyond the knowledge, tools, and techniques that we brought to the

project, typically through collaboration with others whose understanding of science teaching and learning is rooted in other training pathways, professional experience, and personal histories.

Stephen R. Burgin Adam M Siepielski

Student Perspectives of Remote Participation in Authentic Research in an Undergraduate Ecology Laboratory Course

In this presentation, we present findings from the second year of offering an authentic research experience through an undergraduate ecology laboratory course. This project involved a partnership between science and science education faculty. The goal was to include as many undergraduate biology students as possible in an opportunity to conduct authentic experimental research. However, the global COVID-19 pandemic forced us to modify what we had done during the first year of offering the course in order to accomplish the same goals, but now in a remote and online format. We will discuss student perspectives of the differences between this experience and their prior laboratory coursework, and changes in their views of NOS and scientific inquiry that resulted from their participation in our course. Our research demonstrates just what is possible in a remote undergraduate laboratory course and the positive impact that was observed in our students. We hope it serves as a model for other scientists and science educators.

K. C. Busch Lynn Chesnut

Social Network Analysis as a Tool to Operationalize Communities of Practice and Document Social Learning

Individuals or organizations can participate within a social learning system as a Community of Practice (CoP). Many educational interventions aspire to create CoPs to improve individual learning outcomes and group-level functioning. However, operationalizing a CoP can be challenging, making documenting such changes difficult. The goal of the proposed interactive poster presentation is to share the framework and methodology employed in two case studies to illustrate how SNA methods can be used to operationalize a Community of Practice. This methodology is generalizable to any CoP, and as such could be used by other educational researchers who are working to improve the learning outcomes for a group of individuals or organizations and wish to document that change over time.

K. C. Busch Lynn Chesnut

Building Capacity for Collective Evaluation across ISE Centers: A Tested Model for a Collaborative Approach

Science museums and centers have the capacity to contribute to a variety of informal science learning outcomes across diverse populations but understanding if that capacity is being actualized requires collective evaluation. This proposed stand-alone paper presentation will report on the results of a research-practice partnership project between 36 ISE organizations across a state, a state-funded grants

program, and a university, funded through an external source. The goal of the 3-year project was to develop an empirically-tested model for a collaborative approach for building capacity for collective evaluation. We will present the project model and the data to support its use by others who wish to build capacity for collective evaluation in a collaborative way. The model, although tested with ISE providers, is generalizable to other educational efforts.

Sanlyn Buxner Lauren Cabrera

The Intersection of Socioscientific Issues and Classroom Diversity: Affordances and Benfits

Engaging middle and high school students in socioscientific issues (SSIs) has the potential to increase students' engagement in science practices as well as increase connections of classrooms to relevant current issues that matter to students. This case study analysis investigated five teachers who reported teaching SSIs in their classes of diverse high needs students. The classroom contexts included classes with a high percentage of English Language Learners (ELLs), highly heterogeneous classrooms, non-traditional high schools, and students who struggled in reading and writing. Our findings show that these students additionally struggled with the same issues as other students when engaging in SSIs including challenges in using evidence in argumentation, grappling with multiple sources of information, and conflicts with political and religious beliefs. Teachers reported creating and utilizing accessible accommodations to support students in successfully engaging their students in SSIs. Reported benefits for diverse students included increases in their ability to use evidence, increases in language ability, increases in confidence in science, and relevant connections to real-world issues that mattered to students. Our findings support calls for the use of SSIs to support all students in evidence-based practices in ways that support their overall learning.

Lauren Cabrera Ananya Matewos

Student Assertions in Science Discourse Spaces

The field of science relies heavily on discourse and in turn, science learning benefits from open dialogue where students can grapple with evidence to support and refute scientific claims. Socioscientific Issues (SSIs) are used with instruction scaffolds to provide students with a space to practice these discourse skills. Little is known about the dialogic patterns that occur in the small group spaces the instructional scaffolds are typically used in. The study used a multiple qualitative case study design to better understand how and when students assert themselves in these small group settings and the dialogic outcomes of those assertions. It used a sample of six small groups over two timepoints in the sixth grade. Multiple levels of analyses revealed student assertions played an important role in the leadership and understanding of the small group. Implications for practice and research are thoughtfully discussed.

Ryan Cain Victor R Lee

Temperature Measurement with Early Elementary Students

Although all grades K-12 are expected to engage in the science engineering practices called for the NGSS, the early elementary years need specifically designed tools and activities. The purpose of this

study is to investigate how well Kindergarteners can interpret both a typical classroom expansion thermometer and a newly designed Early Childhood Thermometer. Using an interpretive qualitative design to analyze semistructured interviews, we found that all six participants could successfully make acceptable readings of the Early Childhood Thermometer. The findings have implications for better supporting kindergarteners for measuring and making sense of quantitative temperature measurements.

Angela Calabrese-Barton Francisco Parra

Understanding Minoritized Youth Learning through Social Networks during the COVID-19 Multipandemic

COVID-19 has impacted nearly every aspect of life in the US and across the globe. This pandemic presents an example of why scientific literacy, conceptualized broadly to include science concepts, the nature of scientific evidence, and ideas about how science works, is so critical. We contend that it is essential for the spaces of science teaching and learning to be spaces in which complex issues like the COVID pandemic are explored. We contend that the science education community has a key role to play in supporting expanding dialogues and learning about critical societal issues particularly those, like the COVID crisis, which are so critically connected with science. This paper set features work from five research teams which took up the challenge of responding to the pandemic through science education. The researchers come together here to share some of the ways in which science education has been leveraged in the midst of the COVID crisis. The goal of the session is to surface what the science education community has learned through the current crisis, critical research directions that are needed, and how the community can position itself for effectively responding to the next global crisis that will inevitably emerge.

Elena CalderÃ³n-Canales Leticia Gallegos-CÃizares

Science Notebooks in Preschool Education

Notebooks in science activities are tools that allow students of any educational level to represent their way of seeing and understanding natural phenomena and reconstruct their mental representations. They are also tools that allow teachers to assess their students' understanding and improve their teaching practice. The present work shows the results of the analysis of the notebooks made by 25 preschool students from a public school after carrying out a sequence of activities about sound. The analysis of the registration notebooks used in the activities included two stages Components of the registration, which considered those elements that the students included in their worksheets and Levels of representational Redescription. Results show elements from which it is possible to infer the students' ideas about the production, characteristics, and propagation of sound and the transformation of their ideas about this phenomenon.

Nicole Campbell Mohammed Estaiteyeh

Preparing Graduate Students for Success: Validating Interdisciplinary Skill Development Needs

In response to graduate students' need for better personal, professional, and academic skill development, the School of Medicine and Dentistry at a Canadian University developed a new Master of Science degree in Interdisciplinary Medical Sciences (MSc-IMS). To ensure effective program development, a needs assessment was completed. Accordingly, the MSc-IMS was designed to target the following core interdisciplinary skills: 1) complex problem solving, 2) leadership, 3) communication, 4) critical reflection, 5) working in diverse teams, 6) project management, and 7) evidence-based decision making. This research aims to validate these skills by addressing the following research questions: 1) What are graduate students' skill-based needs as determined by their self-assessment? and 2) If, and how do students practice the seven core interdisciplinary skills in their daily lives? A mixed method research design was utilized, in which quantitative and qualitative data were collected using an online questionnaire administered to students enrolled in the program on its first day. Findings show a contradiction between students' personal assessment and practice of those skills. This not only endorses the seven skills reported by the needs assessment, but also provides evidence to support the claim that graduate students in science programs need better skill development opportunities.

Daniel K. Capps Hong Tran

Self-regulated Learning Professional Development for Science Teachers: A Systematic Literature Review

Self-regulated learning (SRL) is a goal-directed process in which learners are active participants in their learning process. Although studies have shown that SRL is critical for success in learning in academic life and beyond, many students do not use SRL strategies to serve their science learning. One way to promote students' SRL is to provide teachers with an understanding of what SRL is and how to develop SRL skills in their students. At present, there have been no systematic reviews on SRL professional development (PD) for science teachers (STs). This critical literature review systematically reports on 14 empirical studies related to SRL PD for STs. We begin by discussing the role of SRL, explain the rationale for this literature review, provide a SRL model, and then examine the salient features and learning outcomes of the SRL PD. Findings revealed that SRL PD used various instructional approaches, lasted for a few hours to a yearlong, had diverse learning objectives, and yielded positive outcomes. The SRL PD supported STs in learning new science concepts, improved teachers' arrangement of SRL environments, enhanced knowledge transfer, fostered constructivist beliefs, increased lesson-designing skills, and developed STs' ability to implement SRL processes.

Lindsay M. Carlisle Victoria VanUitert

Enhancing Performance of Students with Intersectional Identities in Inclusive Science Classrooms via Multimedia Professional Development

Student achievement disparities in inclusive science classrooms are concerning, as knowledge about science, technology, engineering, and mathematics (STEM) is increasingly important for upward

mobility. When students identify with multiple marginalized groups (i.e., intersectionality), achievement differences and progress toward greater outcomes become more troubling, as the interplay among these variables is rarely accounted for in quantitative intervention research. Thus, the purpose of the present study was to evaluate science performance among students with intersectional identities (i.e., students with disabilities from minoritized racial/ethnic groups, n = 33; and students with disabilities from low socioeconomic status households, n = 167) following teacher participation in a multimedia professional development (PD) process using a series of multilevel random intercept models. Results suggest students with intersectional identities who participated in multimedia PD classrooms experienced greater gains across all measures when compared to peers with the same intersectional identities PD intervention process, as well as implications for inclusive middle school science classrooms, will be discussed in this presentation.

Carina M Carlos Vesal Dini

The Authoritative-to-Dialogic Spectrum of Facilitation Practices

One model characterizing instructor facilitation of student learning is the Formative Assessment Enactment Model (FAEM). The model describes instructors' facilitation practices as eliciting or advancing student thinking, guided by their purposes as well as by what they notice about and how they interpret student thinking. Eliciting and advancing moves can be enacted either in authoritative ways, driven by one perspective that has authority, or in dialogic ways, driven by multiple perspectives. While research suggests authoritativeness and dialogicity exist on a spectrum, there is no existing characterization of this spectrum that uses the theoretical underpinnings of these concepts, i.e., the perspectives centered. In the present study, we used the FAEM to characterize facilitation practices of 19 introductory science courses' learning assistants (LAs) during small group discussions, which revealed the existence of an authoritative-to-dialogic spectrum grounded in the perspectives centered. Here we report on this spectrum that reconsiders what perspectives can drive instructor enactment of facilitation other than the perspective of canonically correct science and the perspectives of the students involved in the discussion. This emerging characterization may be used by instructors to intentionally shift between authoritative and dialogic practices in their classrooms.

Sarah J. Carrier Aimee B Fraulo

Unite for the environment: Examining the impact a sustainable livelihoods program on proenvironmental behaviors in Ugandan student households near a biodiversity hotspot

The Kibale National Park (KNP) in Uganda is a biodiversity hotspot, home to one of the largest populations of chimpanzees in East Africa and 12 other primate species (Onderdonk & Chapman 2000; Plumptre et al. 2010). KNP is surrounded by rural communities that rely heavily on subsistence agriculture and natural resources. The study presented here measured the influence of teachers' communications with students and the impact they had on students' and their households' sustainable activities. We evaluated a total of 13 different sustainable behaviors including the presence of a fuel-

efficient stove, waste separation, tree planting, use of kitchen garden (vegetable garden near household), banana growing, and beekeeping. In addition, for those participants that had a farm, we evaluated sustainable farming practices, including multi-cropping, agroforestry, rotating crops, mulching, drip irrigation, use of ditches, keeping garden records, and the use of organic as well as chemical fertilizers and pesticides. Data were collected through surveys and direct observation from the [program - blinded] schools' student households and from households of students in control group schools. Across all behaviors considered except tree planting, [program] households showed greater use of sustainable practices than control households.

Sarah J. Carrier Danielle R Scharen

Teacher Educators and Elementary Teachers Share Goals for Authentic Science and Literacy Integration in the 20th Century Realities of 21st Century Classrooms

Many elementary schools in the United States seem to follow a 20th century model of science instruction that struggles to prepare students for science in the 21st century. Most elementary school policies prioritize reading and mathematics, and science may not be taught daily (Smith, 2020). Using survey and interview data, we present voices of three "expert" populations: 1) elementary teachers, 2) science teacher educators/researchers, and 3) literacy teacher educators/researchers. Each group of experts discusses the need for more authentic science instruction by integrating science with the already literacy-focused school day and providing opportunities for all learners to achieve science literacy. While many of the teachers described interdisciplinary practices connecting science and literacy, their interpretations were often reading an informational science text instead of students' actively engaging in science phenomena. Our teacher educators offer strategies for interdisciplinary instruction are supported by recent decades of learning research (NRC, 2000; 2005; National Academies of Sciences [NAS], 2018). While our data present expert voices reacting to ill-informed policies that limit science instruction over literacy instruction, we recommend proactive, rather than reactive solutions for communication with policy makers.

Michael Cassidy Debra Bernstein

Designing Biomimetic Robots: Examining Middle School Students' Knowledge in an Interdisciplinary Environment

The [Name] is a three-year design-based research project. We developed a 4-week interdisciplinary curriculum for middle school science and engineering teachers that interweaves biology, engineering, robotics, and computational thinking practices, and is aligned with the NGSS and CSTA standards. Instruction is based on problem-based learning, in which students apply science, engineering, and computational thinking practices to address a design challenge. Through design-based research, the project designed an iterated-on pre-post summative assessment, the items of which each include at least two of the curriculum's target disciplines. In year 3 of the project, five teachers from different school districts in New England implemented the curriculum to best fit their classrooms. We found that their students (N=182) scored significantly better on those questions that had been revised through the

iteration process. Findings indicate interdisciplinary questions are difficult to design and more work in this area is needed. In this session, we will discuss the iterative design of the assessment in the context of curriculum redesign over the course of the project as well as the students' results based on each interdisciplinary question. We will also provide curricular materials for an interdisciplinary curriculum that engages students in biomimetic robotics.

Francisco José Castillo Hernández María Rut Jiménez Liso

An Evaluation Proposal for Pre-Service Primary Teachers: Self-Regulation of Learning and Emotions

Research in Science Education has traditionally focused more on cognitive rather than affective aspects. In recent years, and thanks to the accompaniment of other areas of knowledge such as psychology or sociology, this situation is being reversed and the study of affective aspects, such as emotions, has gained importance. In this research, we show an evaluation tool, called Learning and Emotional Self-Reflection Questionnaire, in which 2nd-year students of the Degree in Primary Education have to reflect on their perception of learning and on the emotions they have considered experiencing during the course of a teaching-learning sequence on the floating and sinking phenomenon. Preliminary results seem to indicate that future teachers have perceived learning throughout the teaching-learning sequence and, furthermore, have associated it with emotions such as concentration, interest or satisfaction.

Andy Cavagnetto Nyck Ledezma

Group Dynamics: Examining Group Member Roles in Small Group Data-Based Argumentation Tasks in the context of a Large-Lecture Course

While small group work is often utilized in science education classrooms, little work has examined the social dynamics of such small groups in large-lecture undergraduate settings. This paper sought to a) identify the roles that students take on in this setting and 2) the extent to which students maintain the same roles over time. Lastly, we were interested in whether the style of group leadership influenced the number of alternative ideas occurring in small groups. Thirty-one undergraduate students (11 groups) participated in the study over the two semesters of data collection. Videos from lapel cameras captured student small group argumentation during three primary-data interpretation tasks and were subsequently transcribed. Researchers used a cooperative and iterative process to develop and apply codes. Six roles were identified across the 33 episodes of talk as well as four styles of leadership. Roles commonly shifted within groups across the interpretation of the three data figures. Dominant leaders were the most common type of leader but were also found to inhibit the expression of alterative ideas relative to other types of leaders (Leaders by Necessity & Partnership Leaders). Implications will be discussed.

Riley Ceperich Trang Tran

Science Education Leaders' Sense-making and Noticing for Equity

There is an increasing recognition in the role science has to play in issues of in/equity with respect to opportunities to authentically engage in civic activity from local to global scales. In systems of science education, societal power dynamics and resulting inequities interweave both the challenges of the scientific community and histories of inequity within educational systems more broadly. In this related paper set, we explore findings from a mature research-practice partnership, the Equitable Science Education Research Practice Partnership (ESERPP; pseudonym) project, designed to bring together partners from educational research and practice to promote equity and coherence in science education. Throughout the project, we engage in design-based implementation research to support those engaged in the work of bringing equitable models of teaching and learning into science learning contexts that reflect and extend the vision of equitable teaching and learning in four papers across the ESERPP Project's shared goals to align curriculum, instruction, and assessment through a focus on professional learning through open education resource (OER) development, strategic leadership development, and social organizing across a network of networks.

Vivien M. Chabalengula Ian Nicolaides

Students' Science Learning Interests and Formal Biology Curriculum Emphases: Special Reference to Viruses in the COVID Pandemic Era

This study examined high school biology students' learning interests about viruses and the extent to which the interests were aligned to the formal biology curriculum. Data were collected using a Likert scale and an open-ended survey. The results revealed the following: (a) students were interested in learning about viruses-related content. (b) In descending order, students' self-generated questions revealed that they were more interested in knowing how to prevent/treat viral diseases, diseases caused by viruses, environments where viruses survive/thrive the best, how viruses increase in number, and least interested in the biotechnological applications of viruses. (c) With respect to reasons why the questions were interesting, majority of the students cited acquisition of more knowledge and being aware about viruses, and to verify what they had read about or heard from sources such as media. (d) The greatest percentage of students' questions were at Personal Needs level, followed by Academic Preparation, then Societal Issues, and none on Career Education/Awareness. (e) More than half of the students' questions on virus-related concepts were not aligned to the formal biology curriculum. The implications of these results to science educators and science curriculum designers are discussed. Keywords: Learning interests, biology curriculum emphases, Viruses.

Devasmita Chakraverty

Micro-aggression and impostor phenomenon among racial/ethnic minorities in STEM

Impostor phenomenon (IP) engenders internal conflicts successful people have when they are unable to fully ascribe their success to ability or competence, attributing it to luck, generosity from others, or lack of judgement. Racial and ethnic minorities are particularly vulnerable, and also historically underrepresented in many science, technology, engineering, and mathematics (STEM) fields. Using

cultural-ecological theory, this study examined the research question: "How may racial/ethnic microaggressive experiences in STEM contribute to IP?" Semi-structured interviews from 34 PhD students (Blck:14, Hispanic/Latino) were analyzed qualitatively using a phenomenological approach. Participants were recruited using convenience/snowball sampling for a survey and further interviewed, if eligible. Participants experienced micro-aggression from faculty (including advisors and mentors), peers, and the department/institution/academia. Micro-aggression included inappropriate comments/behavior, stereotyping, and judgment related to looks, identity, external appearances, and the ability to communicate in English. This study offers a rich understanding of race/ethnicity-based experiences of micro-aggression participants related to IP, possibly due to lack of belonging and feeling like outsiders. While mostly studied as an individual phenomenon, IP attributions to discipline-specific and sociocultural experiences were documented. Studies based across cultures, race/ethnicities, and other identity-based dimensions are fewer, and culturally-informed understanding of IP requires more focused studies in the future.

Devasmita Chakraverty

A Cultural Impostor? Native American Experiences of the Impostor Phenomenon in STEM

Even after four decades of research on impostor phenomenon (IP), where people disbelieve their achievements and attribute success to luck, we do not fully understand culturally-relevant experiences of IP among Native Americans in science, technology, engineering and mathematics (STEM). This U.S.-based study examined the research question: "How do Native American PhD students/postdoctorates describe identity-based experiences in relation to IP during academic training in STEM?" Participants were identified/contacted at a national conference on minorities in STEM through purposeful sampling. Seven participants, through surveys/interviews, indicated high to intense IP at the time of interview. Their interviews were analyzed inductively using constant comparative method to identify the following themes in relation to minority identity: 1) Cultural differences and lack of understanding of indigenous culture, 2) Lack of critical mass and fear of standing out, 3) Academic environment, and, 4) Looks and diversity status. Developing a diverse and culturally-competent STEM workforce requires a deeper understanding of what deters Native Americans from pursuing a STEM career; they have the lowest college enrolment and retention rates compared to any race/ethnicity in the U.S. and could be vulnerable to ethno-racial bias and discrimination. Understanding IP through culturally-relevant experiences could help broaden their participation in STEM careers.

Shaghig Garo Chaparian Saouma B. Boujaoude

Developing Argumentation Skills on Socio-Scientific Issues through Evaluating Digital Sources and Engaging in Reflective Discussions

This study highlights the importance of critical evaluation of science media reports in modern society with the prevalence of news and digital sources and their influence on citizens' decisions regarding socio-scientific issues. It investigated the changes in learners' argumentation skills after engaging in reflective discussions following alternative information evaluation in the context of socio-scientific

controversial issues from the perspective of the Family Resemblance Approach (FRA). Participants were sixteen seventh-grade students in a K-12 coeducational private school. This study used a qualitative research design. Participants filled out the argumentation pre-and post-tests, engaged in explicit instruction about information evaluation criteria, evaluated information about alternative views regarding four controversial social issues using Model-Evidence Link (MEL) diagrams, and engaged in reflective discussions which were designed based on the FRA framework. The results showed a remarkable increase in the number of participants formulating the highest level of arguments in the posttest. It also indicated an improvement in the average scores of the alternative information evaluation and the ability of the participants in formulating the highest level of arguments throughout the research study. The results may encourage practitioners to use the FRA framework to design instructional activities and promote several aspects of scientifically literate citizens.

Angela M Chapman Ariana Garza Garcia

A community of practice contextualized within sociocultural phenomena: Mitigating teaching and learning of STEM through counter-praxis

This symposium introduces a counter-praxis framework as a way of preparing pre- and inservice teachers to address the context of the classroom, namely the sociocultural, political, and historical factors that have marginalized and disenfranchised students because of gender, race, ethnicity, socioeconomic status, native language, and immigration.Counter-praxis utilizes LatCrit's counter-storytelling and teacher agency. This research describes how preservice and inservice teachers have developed their counter-praxis by engaging in counter-storytelling in a community of practice. The authors are science education faculty and inservice teachers. By sharing their own experiences, they developed an awareness of the social inequities that positioned them as lesser, ultimately leading to their agency as teachers that empowered them to push back against systemic inequitable practices in their classrooms. This symposium will share the findings from this research and engage in critical discussions about how they enact agency in their classrooms today.

Mindy J. Chappell

Ethnodance as a Critical Identity Tool for Black Students' Science Identity Construction

This study explored how an arts-based practice, namely ethnodance, as a methodological tool, offers Black youth with dance identities a medium to narrate evolving science identities, communicating meanings, interactions, and emotions, and to further construct their identities as reified artifacts of their engagement in science spaces. The theoretical argument frames ethnodance as an embodied narrative of experience, identity construction as an ongoing process with interactional and affective commitments, and dance as a venue of expressivity of the brilliance and creativity of Black people. Five Black student dancers choreographed dance performances that became embodied representations of their narrated experiences in science and their science identity construction. They used ethnodance to construct who they were and were becoming vis-à-vis science, transducing emotions within their science experiences and those associated with their agentic choices, resistance, and advocacy. Their ethnodances conveyed how changes to the science course sequence, physics discourse, and trusted adult's expectations limited or hindered their participation in science, and how their agency constructed, de-constructed, or re-constructed their competence in science. The study suggests that young people need to be reflecting on identity authoring in the process of experiencing science through modal ensembles that also allow them to interrogate this authoring.

Regina Ayala Chavez K. C. Busch

Adolescent Framings of Climate Change, Psychological Distancing & Implications for Climate Change Concern and Behavior

It is essential to understand how youth are framing climate change in order to develop effective educational opportunities and targeted communication. In this paper, we asked 453 youth from the Western U.S. to describe climate change, in their own words. Their open-ended responses were qualitatively analyzed to determine the frames employed. Then, a semantic network was used to visualize how frames co-occurred and to develop discourses. The dominant Physical Science Discourse told this story: Human-caused climate change will affect global physical Earth systems negatively in the future. The less common Social Discourses told this story: Climate change is a current issue that is affecting people, plants and animals at a local scale, for which we will have to seek methods to mitigate and adapt. The Physical Science Discourse instantiates a greater psychological distancing from climate change. Youth who used the Physical Science Discourse reported statistically significant less concern about climate change than the students who used the Social Discourses. There was not a statistically-significant difference for mitigating behavior. This research suggests the need to communicate climate change in ways to decrease youth's psychological distancing, connecting it to people, social systems, local places, and to the present time.

I-Chien Chen Tingting Li

Curriculum-Aligned Instruction and Formative Assessments: Promote Students' Academic and Social-Emotional Learning

Promoting social and emotional learning (SEL hereafter) for teachers and students has become an essential priority in many states. Relatively little is known about what curriculum-aligned features (e.g., goal driven, activities driven or teacher-student feedback) serve as a sustainable method to promote and monitor a long-term improvement of academic, and SEL. This study leverages Multiple Literacies in Project-Based Learning (ML-PBL) program to understand three social processes in promoting students' academic and SEL competencies. We will conduct two studies to first identify the three processes between teaching instructions and formative assessments, and then examine their impacts on students' performance in several conditions. Multi-level structural equation modeling (MSEM) approach was employed to simultaneously estimate the relationships among unit-specific activities, reflection of community, students' academic and SEL competencies. Initial results show significant relationship between curriculum-aligned features and students' performance, as well as teacher strategies and SEL. Our study will aim to fill the literature gap of what counts as a sustainable method of curriculum-aligned intervention programs on children's academic and SEL improvement.

Sufen Chen Ssu-Ching Huang

A Longitudinal Study of Middle School Students' Science Task Values

This study used a latent growth curve modeling approach to investigate the developmental trajectories of middle school students' task values in science. Gender differences over time were also examined. Data of four task values, including attainment value, intrinsic value, utility value, and cost, were collected from 423 students in Taiwan. Students' task values were surveyed every semester from the seventh grade to the ninth grade. The linear latent growth model had good model fit to interpret the patterns of change over time. The results indicated that students' attainment value and intrinsic value in science showed a significant decreasing trend. Their utility value was stable over time. Cost, on the other hand, was increasing. Girls expressed lower intrinsic value in science. The results of this study based on longitudinal data give direction to educational practitioners and policymakers for sustaining students' science task values as well as broaden theoretical knowledge about the trends of adolescents' task values within the Taiwanese context.

Xiao Chen Sihan Xiao

Emotions in Science Learning and Teaching: A Systematic Review

The COVID-19 pandemic and other science-related social issues make visible the decisive role of emotions (e.g., excitement, fear) in people's everyday use of science. To explore the underlying mechanism, this review systematically analyzed 22 studies on the emergence and the impacts of emotions in the science classroom as well as the strategies to provoke positive emotions. The results showed that: (1) students' emotions emerged and changed during the process of finishing learning tasks and interacting with their teachers and peers, (2) positive emotional experiences promoted students' learning outcomes and learning process, and (3) science educators could elicit positive emotions by providing appropriate tasks and supportive learning environments. We discuss the role of emotions and feasible solutions to evoke positive one for science teachers.

Ya-Chun Chen

Investigating the effect of context-based teaching on students' science engagement and perceptions of utility value

抽象的: This study explores the effect of integrating context-based problem-solving activities into teaching on high school students' engagement in science and perceptions of science utility value. Twenty-seven 11th grade students from a private comprehensive school were invited to participate in this study. Context-based problem-solving learning was integrated into the 18-weeks course. The questionnaire of Engagement in Science and perceptions of science utility value with a four-point Likert

scale was used in this study. The dependent t-test was used for data analysis. The results show that high school students make significant progress in emotional (interest in science and enjoyment of science), cognitive (self-efficacy in science and self-concept in science), and behavioral (participation in science-related activities) engagement in science, and perceptions of science utility value after the intervention of context-based problem-solving learning (p <.001)。關鍵詞:基於情境的問題解決學習,參與科學、對科學效用價值的認知

Meng-Fei Cheng Yu-Heng Lo

Innovative STEM curriculum to enhance students' engineering design skills and attitudes toward STEM

Although STEM education has been advocated internationally, the integration of interdisciplinary learning into STEM education and the gender disparity in the STEM field are challenging. Our research team in Taiwan developed a female-friendly and innovative STEM curriculum with flat (rather than bulky) speakers to enhance male and female students' creativity in developing new technology and to foster their interdisciplinary thinking. Participating year 10 students were encouraged in the 3-hour course to integrate science knowledge into their engineering design processes in order to better develop, evaluate, and revise their technology products. In this study, we examined this STEM curriculum to show the progression of male and female students' engineering designs and their attitudes toward STEM. We identified gender differences in their learning performances. The study findings can contribute to the development of better ways of integrating interdisciplinary learning and teaching and enhancing male and female students' engineering designs and attitudes toward STEM.

Kevin Cherbow

Responsive instructional design for students' coherence-seeking: Documenting episodes of principled improvisation in storyline enactment

Curricular materials, such as storyline science units, are valuable resources for teachers because they organize students' efforts to make progress on their scientific questions and problems. However, in enactment, the teacher sometimes has to diverge from the planned trajectory to follow students as they seek unanticipated coherence in the curriculum. In this single case study, I used interaction analysis to document episodes of whole group discussion where one experienced middle school science teacher attended and responded to his students as their coherence-seeking diverged from the planned trajectory in the storyline. The results suggest the teacher facilitated episodes of principled improvisation (PI) related to the students' interactive role in discussion, the science ideas they raised for a consensus model, and the measurement errors they experienced in investigation. These episodes were principled because the teacher foregrounded particular trajectories in the storyline to mediate and add rigor to the students' divergent lines of coherence-seeking. They were improvisational because the teacher backgrounded other trajectories to more effectively share epistemic agency with students. Overall, these findings show the analytical and practical value in conceptualizing epistemic agency and teachers' instructional design work in relation to students' coherence-seeking work in the curriculum.

Ann Childs Liam Guilfoyle

The enactment of professional development principles in a collaborative project between science and RE teachers

Teacher educators and scholars of teacher education have often recommended the development of professional development experiences around key principles. While many scholarly texts suggest and review such principles based on research evidence, few have studied the enactment of these principles in practice. This paper reports on a self-study of the enactment of such principles in a collaborative professional development programme between teachers of science and Religious Education (RE). We draw on a wide corpus of data from the project, including planning documents, meeting records, recordings and materials from workshops, surveys and interviews, as well as our own personal reflections as teacher educators. In analysing the data, there is ample evidence the principles were indeed enacted and that in many instances their enactment interacted, supported, and build on each other. However, we also recognised that some were more challenging to enact than others and others produced unintended consequences. The findings of the self-study have implications beyond our own practice by offering transferable understanding to the field about how research-informed professional development principles might be practically operationalised, particularly in collaborative settings. Other teacher educators will benefit from the exploration of the challenges and opportunities included in this paper and the critical reflection on the enactment of professional development principles. The identification of key areas of tensions and areas for improvement can be generative for further research and discussion in teacher education. Finally, the paper advances the consideration of unity and inclusion in science education through meaningful collaboration with teachers of other subjects.

Pauline W. U. Chinn Bhaskar Upadhyay

Indigenous science knowledge as social and cultural capital supporting more resilient and sustainable communities

Indigenous communities with generations of knowledge, practices, and values finely tuned to living sustainably in both urban and rural places (Buck, Chinn & Upadhyay in press) have much to contribute but often are overlooked and left out of social networks involved in participatory community planning. This leads to inequities within communities, increased vulnerability for indigenous groups, and overall lower resilience. The proposed ISK Administrative session is particularly appropriate to the NARST Conference theme "Unity and Inclusion for Global Scientific Literacy: Invite as a Community. Unite as a Community" for the following reasons. There are urgent needs to conserve, document, transmit Indigenous knowledge, language, and biocultural heritage oriented to sustainable, resilient social ecosystems in the current context of climate change, COVID-19 pandemic, globalization, unsustainable land use, and land loss. Presenters from diverse cultures and geographical locations will provide a global as well as local perspective on indigenous science knowledge as the cultural capital with a role to play in STEM education and research where issues of equity, access, and ecological justice exist." Finally, the administrative session provides a forum to join voices to share and address indigenous and curriculum indigenization issues now and going forward.

Ren-Jye Chou Hsiao-Ching She

Research of Online Scientific Inquiry with/without Computer Simulation on 8th Graders' Performance of Scientific Inquiry

This study aims to compare the effectiveness of online scientific inquiry between the group with computer simulation and without computer simulation on 8th grade students' performance of scientific conceptual understanding and scientific inquiry involving the spring unit. We also examined whether high and low achievers' perform differently after online scientific inquiry. 58 students were assigned into the scientific inquiry with computer simulation, while the other 59 students were assigned into the scientific inquiry without computer simulation. Both groups received online scientific inquiry involving spring topic for six-class periods which consisted of seven topics of spring related experiments. Results showed that the group with computer simulation significantly outperformed than the group without computer simulation significantly outperformed that the group with computer formed than to the group without computer simulation from topic 4 to 7; while the discrepancy between high- and low-achievers was minimized to non-significant from topic 5 to 7. Our findings demonstrated that computer simulation could enhance students' scientific inquiry better than non-computer simulation, and also could close the gap between high and low achievers' online scientific inquiry processes.

Devon M Christman Kassandra Ortega

Youth Science Identity and Perspectives of Scientists after Participation in a STEM-based Afterschool Program

Historically, disciplinary professionals associated with science, technology, engineering, and mathematics (STEM) have been predominantly white and male and such predominance continues to the present time. Even though young girls are more likely to rate science as their favorite subject more often compared to boys, girls are less likely to garner STEM careers. As of 2019, women in the U.S. constitute only 27% of the STEM workforce, even though they contribute to nearly half the workforce in the country. To increase diversity in STEM, many high schools and colleges have created initiatives to get students interested in science. However, research has shown that targeting this age range of students might be too late to foster a love for STEM. We partnered with a local afterschool program to help 20 young girls and non-binary youth (ages 9-11) develop or strengthen a STEM identity and gain a more gender-inclusive perspective of scientists by introducing them to women STEM professionals at a local university. We interviewed the youth before and after their participation in the program to gain insights into how identities and perspectives developed over the course of this 20-week program.

Heidi Cian Remy Dou

Durability of Systemic Gendering of STEM in College STEM Students' Definitions of a STEM Person

Individual self-perception (i.e., identity) in STEM is influenced by how individuals understand their personal fit with the values, norms, and behaviors—or Discourses—of the STEM community. In STEM, these Discourses typically reflect masculine priorities and values, such as drive for competitiveness and objectivity. Consequently, women and characteristics associated with the feminine are distanced from the STEM community, and women's capacity to participate in STEM is dictated by their preparedness to adopt these dominant Discourses. These exclusionary practices are resilient, in part, because of their invisibility, as STEM actors adopt them unconsciously and reinforce the dominant Discourses. Drawing from theoretical framings of social identity and critical feminism, we study the subtly gendered ways that current college STEM students define what it means to be a STEM person as they reflect on the STEM persons in ways that reinforce masculine ways of performing and distance STEM participation from the feminine. Further, we find that criteria for membership are often differentially applied, especially in contrasting mothers and fathers.

Ayse Ciftci Mustafa S. Topcu

Computational Thinking (CT) Integrated STEM Approach: Early Childhood Pre-Service Teachers' CT Skills

The purpose of the current study is to compare the effects of CT integrated STEM and STEM approaches on early childhood pre-service teachers' CT skills (creativity, algorithmic thinking, critical thinking, problem solving, cooperativity, communication). A total of 70 pre-service teachers were involved in the study. In the study designed as a quasi-experimental design, CT integrated STEM approach-based activities were conducted with the experimental group students and STEM approach-based activities were conducted with the control group students. The data were collected through the 'Computational Thinking Scale' and analyzed with the non-parametric ANCOVA (Quade method). As a result of the analysis, significant differences were found in the post-test total score and post-test scores taken from the sub-dimensions of algorithmic thinking and cooperativity in favour of the experimental group. These differences show that CT integrated STEM approach is more effective than STEM approach in developing pre-service teachers' CT skills.

Dante Cisterna Lei Liu

Exploring Student Reasoning Patterns in the Context of a NGSS-Aligned Assessment Task: The Harvestmen Item

to consider opportunities to effectively capture the richness of student reasoning patterns, which are key to support students' understanding of science. This study explores the reasoning patterns that sixth, eighth, and tenth grade students exhibited when answering a constructed-response, NGSS-aligned assessment item about explaining the effects of introducing a predator into a cornfield ecosystem. Drawing from research on student reasoning and the NGSS tridimensional framework, we identified three distinctive reasoning patterns that students rely on to answer the item question. Working with 661 responses to the item, we developed a framework to identify each reasoning pattern and examined frequencies of student responses to the item based on reasoning patterns and other science learning measures. We also examined how the use of artificial intelligence (AI) techniques can be used to build an automated model to predict each reasoning pattern in student responses to the item. Findings suggest the feasibility of identifying reasoning patterns in student responses and text segments associated with such patterns. The study has implications for the development of feedback tools that can support teachers and students aimed for complex and integrated reasoning in science.

Heather F. Clark Imelda L. Nava

Computational Thinking Integration in STEM Pedagogy by Teacher Candidates

This study investigates an urban teacher residency program oriented to the development of social justice educators who can meaningfully integrate computational thinking (CT) in science and math pedagogy. Drawing on artifacts from their coursework and teaching, as well as interviews, we document the ways in which novice teachers integrate CT and the factors that support this integration. We present findings on how teachers integrated CT as a scientific practice, included components of the data cycle in warm-up activities to orient lessons, framed the purpose of their courses as problem solving, and promoted CT as an opportunity for growth mindset. This integration was supported and motivated by coursework oriented to developing both conceptual knowledge and pedagogical practices, beliefs in the value of locally and socially relevant data to support meaningful learning, and teachers' prior experience with computer science. These findings call attention to salient features of teacher education programs that promote teacher learning around CT and offer practical examples of how teachers integrate CT in their pedagogy.

Heather F. Clark Darlene Tieu

Scaffolding Sociopolitical Dimensions of Climate Change in Diagrammatic Models

This study explores an approach to learning about climate change through the NGSS-promoted practice of modeling as a phenomenon that is inherently scientific and sociopolitical. Through a design-based research partnership in a chemistry class of Black and Latinx students, we designed a series of scaffolds to support youth in creating diagrammatic models of climate systems that include sociopolitical dimensions. Analysis of 13 students' models was guided by a holistic rubric to evaluate components, processes, sequences, local context, and generativity. Results show that students frequently included economic, political, justice-oriented, and community-centered features to explain why their city was warming and what actions can reduce greenhouse gas emissions. Findings suggest that our scaffolds provided students with opportunities to model sociopolitical dimensions as inseparable from scientific dimensions. The mechanism of the greenhouse effect that student modeled was incomplete representing the challenges of modeling and the limitations of our design. We contribute an approach to climate change instruction that advances justice-centered science pedagogy.

Ted M. Clark Glenn A Clark

Did COVID-19 & Distance Learning Heighten Performance Disparities in General Chemistry?

Achievement gaps are well-documented in introductory STEM courses as subgroups based on gender, underrepresented minority status, or first-generation college status underperform their classmates. Researchers have investigated achievement gaps involving final grades and course assessments such as exams or labs, with and without controlling for measures of incoming preparation. It is generally found achievement gaps are reduced, but not eliminated, after accounting for incoming preparation, and that models of final exam performance have limited predictive power if they are based solely on subgroup variables. This investigation has conducted a similar study but with a novel student population, which is students in general chemistry courses that suddenly transitioned from in-person to online teaching and learning in response to COVID-19 and comparing the spring 2020 semester with historical data from the previous 3 years. Results agree with the general findings, as achievement gaps exist for exams and final grades, and these are reduced but not eliminated by controlling for ACT score. Significantly, gaps did not differ in spring 2020. However, factors predicting success on the final exam dramatically changed and the overall predictive power of the models was reduced as exams completed earlier in the semester (in-person) became much less significant.

Ted M. Clark Nicole Dickson-Karn

Strategies undergraduate students use to solve a volumetric analysis problem before and after instruction.

The strategies students in general and analytical chemistry courses use to solve a typical and challenging volumetric analysis calculation have been investigated using an open-response show-work problem set. Prior to instruction performance is poor (26% correct) and about one-fourth of the students cannot recall a strategy to solve this algorithmic problem. After instruction performance improves in both courses but remains low, near 50%. Most frequently used strategies before and after instruction are calculating mole amounts and applying the formula M1V1=M2V2. Calculating mole amounts is shown to be a superior strategy when the stoichiometric mole ratio in the calculation is 1:2 rather than 1:1, with the M1V1=M2V2 strategy being very susceptible to errors with this mole ratio. A flawed approach involving proportional reasoning has also been identified, which was present on pretests but not posttests. Notably, although a M1V1=M2V2 strategy was popular among students before and after instruction, it was not included in classroom instruction. It is significant that many students recall or "find" a strategy on their own to answer a common algorithmic problem, yet the strategy is frequently used incorrectly.

Hernan Cofre Francisca Carmona

Describing changes in Student thinking about evolution in response to inquiry and argumentation-based instruction

The main objective of this research was to characterize the nature of the change in student thinking about evolution through the mechanism of natural selection during a six-lesson using inquiry and argumentation as instructional strategies with a group of eleven-grade students (16-17 years old) from a private school in a South American country. The data were collected through the ACORNS questionnaire before and after the intervention, the analysis of worksheet for each activity carried out and individual exit tickets answered at the end of each lesson. This information was analysed generating categories based on pre-established rubrics in the literature on understanding evolution. The students' level of argumentation was obtained by analyzing the transcripts of the work of each of the groups formed in each class using the guideline developed by Larrain et al. (2020). The main patterns described here are the recurrence of the design teleology explanation in students, the initial use of key concepts such as mutation, survival, and differential reproduction during the trajectories.

Karen Marie Collier Margaret R. Blanchard

The development and validation of the graduate student success survey: A quantitative study

Student success during graduate school is influenced by a wide range of factors, including students' sense of belonging, feelings of imposter syndrome, the quality of mentoring relationships, and experiences of microaggressions and microaffirmations. These can differentially affect students from underrepresented minorities (URM), females in STEM, and first-generation college students. To better understand the experiences of university graduate students, a survey, the Graduate Student Success Survey (GSSS), was developed and validated. Item development led to the distribution of the initial survey invitation to approximately 4,500 students at a research intensive university in the southeastern U.S. The completed surveys (N = 537) were split into two samples. The first sample was tested for reliability and validity with exploratory factor analysis; confirmatory factor analysis was conducted on the second sample. Preliminary survey results revealed that some subgroups, including females and URM, were less likely to feel a sense of belonging and more likely to feel imposter syndrome. Final survey items and tentative recommendations will be shared.

Mandi Collins Elizabeth X. De Los Santos

Developing Scientifically Literate Citizenship: Self-Efficacy Beliefs of an Interdisciplinary Community of Practice

This qualitative multiple case study explored a middle school community of practice, composed of English language arts (ELA), science, and social studies teachers, as they share interdisciplinary experiences supporting students to become scientifically literate citizens. Teachers' self-efficacy beliefs (Bandura, 1986) are utilized as a lens in which this question is investigated because outcome expectancies and efficacy expectancies will help identify what teachers' needs are to better support the development of students to becoming scientifically literate citizens. Two themes were identified for outcome expectancies including an emphasis on skills and character attributes during instruction and rooting instruction in phenomena and current events. A single theme, internal and external challenges outweigh school-wide supports in students' development to become scientifically literate citizens, was identified for efficacy expectancies. This study lends to contributions about what we know and understand about teachers' beliefs in meeting the goal of developing students to become scientifically literate citizens and is informative for those engaged in supporting interdisciplinary interactions of teachers working within a community of practice to be successful in achieving shared goals.

Brandin M Conrath Kathryn M. Bateman

Argumentation with Summary Tables in geoscience learning

One of the many tools developed by the Ambitious Science Teaching (AST) Framework, the Summary Table is used as a structuring document for students to organize their thoughts based on classroom discourse regarding an anchoring phenomenon (Windschitl et al., 2018). While students work to complete the Summary Table, they engage in sustained conversation where they compare and contrast ideas through public critiques to argue and build new science ideas. In this study, we examine the interactions and discourse of a middle school classroom as they complete the Summary Table and make summative arguments within a locally called, CER Journal, during the implementation of an online plate tectonics curriculum. Preliminary findings illustrate that creating time and space for scientific discourse provided students with sense-making opportunities around the complex science ideas to support their explanations of the phenomenon. The Summary Table scaffolded development of increasingly sophisticated explanations by providing a structure for students to connect observations with the driving question of the unit. Specifically, the Summary Table supported small and whole group discussions positioning students to argue and partake in open critique of their claims and evidence in diverse and increasingly public ways as they develop sophisticated science explanations.

Judith A. Cooper-Wagoner Kristin L. Gunckel

Preservice Teacher Noticing, Interpreting, Responding to Students' Sensemaking Resources for Equitable Access to Science Understanding

Teacher proficiency in noticing, interpreting and responding to students' resources (ideas and cultural knowledge) to make sense of science is essential in equitable teaching. There has been little research on how elementary science preservice teachers grow in sophistication in these practices. In our qualitative study, we used a teacher noticing, interpreting and responding to students' sensemaking resources framework to compare the similarities and differences among three preservice teacher groups at different points along a learning to teach science trajectory. Focus was on the groups' interpretations of students' sensemaking resources. Data was from participants' written comments about what they noticed and how they interpreted and responded to what students said and did in video clips featuring students discussing science. The written comments were used to generate individual semi-structured interviews to gain deeper insights to the teacher groups' interpretations. We analyzed the data by applying a constant comparative method. Our findings show that the differences in the teacher groups' interpretations were shaped by the varying contexts from which they engaged in the practices. Gaining

insights into how preservice teachers grow in sophistication in noticing, interpreting and responding to students' sensemaking resources is important for equitable science teaching and learning.

Deborah Cotta Danusa Munford

Interacting with Luna: Scientific characters and 3rd graders' construction of relationships with Science

In this study, we investigate how a group of 8-9 years old children constructs relationships with science after interacting with the characters of Earth to Luna! at home and participating in activities to share their experiences with theirs peers at school. This study was conducted in a public lottery school located in a big city in Brazil, in a classroom with 24 3rd graders (12 boys and 12 girls), for three months. The main data source was participant observation with records in field notes (Spradley, 1980) and in video. Moreover, we collected artifacts produced as students' participated in the activities at school or at home (e.g., students' texts and drawings, and notes on the blackboard). The results indicate that the process of constructing relationships with science is not linear and it depends on interactions in classroom. Our study has potential to contribute to teachers understandings of how to mediate interactions to promote a better use of media resources. Moreover, it can contribute with new insights into methodological approaches to investigate the influence of media with a focus on classroom discursive interactions that goes beyond the content of children's/instructor talk and also considers forms of participation.

Brock Couch Grant E. Gardner

A Systematic Literature Review on the Use of Social Network Analysis in Discourse Studies

Current policy documents have called for K-12 and higher education to integrate instructional methods that align more with science, technology, engineering, and mathematics practices used by professionals (e.g., American Association for the Advancement of Science, 2011; Honey, Pearson, & Schweingruber, 2014). Of these instructional methods, promoting professional discourse between students has become a pervasive and useful practice within science classrooms (Kelly, 2007). In a recent essay, Wagner and Gonzalez-Howard (2018) discussed the usefulness of social network analysis (SNA) as a methodology for understanding the interaction between students in discourse studies within education. To build from the work of Wagner and Gonzalez-Howard (2018), this literature review focuses on collecting and synthesizing discourse studies in educational contexts that use SNA to understand how the method has been leveraged. For this literature review, I followed the PRISMA Group methods of inclusion (Adapted from Moher, Liberati, Tetzlaff, Altman, 2009) using the search terms social network analysis and discourse, which yielded 41 articles. For this proposal, I discussed two of my research questions (RQ4 & RQ5) to highlight the flexibility of SNA. For discourse studies, the flexibility of SNA offers a unique analysis that has the potential to provide new insights on discourse.

Joshua Cruz Rebecca Hite

"We're Not that Different": Typologies of Guests' Relationships to Museum Objects via Mechanic Assemblage within a Dinosaur Gallery Museum galleries foster guest-and-object engagement to create singular experiences where they may develop and refine knowledge of topics related to history, art, and science. This assemblage of meaning is interesting for museums which present scientific information, especially if that information is abstract or controversial, like a dinosaur gallery. This study examined photographs taken by 50 patron-participants (i.e. guests) within a mid-sized museum dinosaur gallery that serves a population of 250,000 people. Participants' photographs (N = 566) of objects including artifacts, signage, fossils, etc. along with 50 verbal surveys comprised the data set. We used a Deleuzo-Guattarian framework paired with a post-intentional phenomenological methodology to identify areas of guests' evocation (the "comings-together" between participant and the object photographed) and assemblage (the product that participants create as they engage with gallery objects forming reactions, perceptions, knowledge, etc.) when exploring the lived history of dinosaurs. Findings suggest common assemblages related to the lived experience, common to that of people, living, eating, raising a family, and dying. Leveraging aspects of lived experience such to foster that parallel to the guest may improve guests' experiences and learning of science.

Christine M. Cunningham Gregory J. Kelly

Preparing Pre-College Students to Solve Emerging Interdisciplinary Problems: Integrating Life Science and Engineering in Classrooms

The Framework for K-12 Science Education emphasizes the importance of learning through both the science and engineering practices. While many projects emphasize the development and evaluation of instructional materials that emphasize learning life science content through the science practices, less attention has been brought to how the practices of engineering can be a vehicle to teach science content. Even more, most programs that foster learning through both science and engineering practices center on disciplines such as physical science. During this symposium, participants will learn about four projects and the integrated instructional materials (activities, professional development, assessment, and teacher supports) they have created. Each team will discuss the development, benefits, and outcomes of learning life science through both the science and engineering design challenges in life science classrooms, there are common threads about how integration can be done in meaningful ways. These include (1) necessary connections to central themes that drive the science content and engineering, (2) support for students in the social process of engineering through scientific discourse, and (3) the need for clear support to guide teachers in classroom integration.

Kimberly Ann Currens Sandra B. Nite

Spatial Drawing Ability: Informal Learning Experiences

Spatial visualization skills are essential in science and other STEM careers. Summer camps offer informal education experiences that provide students with a stress-free learning opportunity. Students in a summer camp (n = 60) participated in various spatial awareness and visualization courses. Students increased their spatial visualization and drawing abilities throughout the one-week camp. Hedge's g effect size for the difference in mean scores for the two groups was 1.007 (p = 0.02). Experience working

with 3-D software can improve student's spatial abilities, and better prepare them to study in many science fields.

Rebecca Curtright Sylvia Scoggin

A District Perspective on the Use of Science Assessment Data

This related paper set presents the results of our work developing and implementing a threedimensional district biology assessment within the context of a research-practice partnership. We include our practice partners as lead co-authors to demonstrate our commitment to valuing practice perspectives in science education. Paper 1 describes the district science curriculum coordinator's decision-making about the development of the assessment, including successes and challenges of the process. Paper 2 describes how the district implemented the assessment and used the data from administration of the assessment to all high school biology students in the district. Paper 3 investigates teachers' professional learning experiences as an item writer on the assessment development team. Finally, Paper 4 investigates students' reasoning on the assessment using a think-aloud protocol. Altogether, these four papers highlight different aspects of the development and implementation process of a district science assessment from both practice and research perspectives and contributes to our understanding of the challenges of enacting educational reforms in complex educational systems.

Dennis L. Danipog Suzanne Rice

Assessing the Inquiry Practices of Teachers in the Philippines

Most research on the use of inquiry in school science to date has been conducted in developed countries. It is not yet known whether and how teaching through inquiry, which is advocated by most developed countries, translates to less developed countries. With this, this study was conducted to assess how the sample teachers from a less developed country, the Philippines, delivered the new Grade 7 inquiry-based chemistry curriculum in the classroom. A Scientific Inquiry Teaching Observational Instrument (SITOI) was developed for this study. Using the SITOI, data were collected through 57 lesson observations from 10 teachers in four public secondary schools in Manila. Analysis of data revealed that teachers seemed to be more comfortable to enact the inquiry practices of engaging in questioning and communicating information than the practices of designing and conducting investigations, collecting data, analyzing data, and developing explanations in chemistry teaching. Teachers used inquiry in challenging teaching and learning environments with the following behaviors: (1) they may tend to prioritize certain practices of inquiry more than others, (2) they may shift from inquiry to another teaching approach depending on school and classroom contexts, and (3) they may implement inquiry in classrooms with scarce resources using improvisation.

Emily A. Dare Joshua A. Ellis

The Current State of Integrated STEM Education: Comparing Science Content Areas and Grade-Levels

Despite its presence in policy documents and classrooms, defining integrated STEM education has been a challenge, delaying the development of observation protocols to understand how STEM education is being practiced in K-12 classrooms. Our work uses a new 10-item observation protocol designed for integrated STEM teaching in K-12 science and engineering classrooms. Using a database of over 2000 video-recorded classroom observations of integrated STEM instruction, this related paper set provides new research that allows the project team to begin to assess and understand current methods of implementation of integrated STEM in K-12 science classrooms. This related paper set includes a series of four studies that highlights how the new observation protocol can be used to understand current classroom practice as it relates to current reform efforts, including comparisons across different classrooms, explorations related to the nature of integration, and the importance of mathematics integration. Our findings suggest that there is much work to be done related to K-12 integrated STEM instruction. The collective knowledge gained from this work can help researchers and teacher educators design professional development for in- and pre-service science teachers to support them in their efforts towards successfully integrating STEM to meet current science education reform efforts.

Jenny M Dauer Irfanul Alam

Exploring the concept of scientific civic engagement and its role in developing science literacy skills

To achieve science literacy students must first be able to transfer the knowledge and skills they have learned in formal classrooms to their own lives and communities. Scientific civic engagement (SCE) is defined as when people find utility in scientific knowledge and skills during civic engagement and is composed of scientific civic self-efficacy, knowledge, action and value. We found that SCE has a positive relationship with a students' perceived cohesion to the students' chosen community, and a positive relationship with students' science identity. In a large-enrollment post-secondary course focused on science literacy outcomes, we found pre-to-post course increases in SCE related to civic knowledge. The themes found in open-ended responses suggest that students have varied ideas about how the science literacy skills learned in the course can be useful to support the goals of their communities. This work begins an exploration of the concept of SCE that has foundations in situated cognition, transfer and identity theories. Implications of this work extend to how to successfully teach all learners science literacy skills and knowledge that would empower them to improve their communities, and to draw connections to students' own lived experiences.

Jodi Davenport Sierra McCormick

Evaluating the Impact of Online Activities Designed to Help High School Students Reason like Chemists

The Next Generation Science Standards aim to help students learn the reasoning and practice skills of scientists, rather than rote memorization, by urging teachers to guide instruction through real-world phenomena and promote critical thinking through inquiry-based learning. The current paper explores whether a set of online activities that aims to bring the three dimensions of NGSS into high school chemistry classrooms may promote reasoning skills. ChemVLab+ consists of eight freely available, online activities that integrate core concepts with investigations in authentic contexts. Students can conduct experiments using virtual labs and receive timely feedback as they plan and carry out investigations,

interpret data, and create explanations. Using a randomized control trial design, we compared learning outcomes of students using the ChemVLab+ activities with students completing a set of active control activities that reflected more traditional instruction and problem solving.

Shannon G. Davidson Sherry A. Southerland

It's the work that it does, not the object itself: Scientific posters as boundary objects

Current visions of science education advocate that teachers engage students' disciplinary learning in the classroom in ways that mirror the work of scientists to develop science proficiency. Yet few science teachers have had firsthand experiences in scientific research or have knowledgeable expertise about the community of science and its norms, practices, and ways of communicating and constructing knowledge. As professional development contexts for science teachers, Research Experiences for Teachers (RET) programs—in which teachers engage in research with scientists—are potentially fruitful contexts for supporting teachers' understandings about science and the ways in which their learning about science impact and translate to their classroom communities and teaching practice. In this study, we examine how a particular artifact of teachers' research experience—a scientific poster teachers create as their culminating activity—served as a boundary object that allows teachers to consider and communicate their learning across their scientific research community and school community. Drawing from interviews with RET alumni, we explore the ways in which these posters—as visible markers of teachers' research participation— allow teachers to feel and be seen as legitimate participants of science across two social worlds.

Elizabeth A. Davis Amy Stephens

Enhancing Science and Engineering in Preschool through Fifth Grade: A National Academies Consensus Study

In this symposium, we present an overview of a consensus study conducted by the National Academies of Sciences, Engineering, and Medicine (NASEM) focused on enhancing science and engineering in prekindergarten through fifth grade. A committee of 16 scholars and practitioners from across the US gathered over the course of 15 months to synthesize the literature and develop a set of conclusions and recommendations based on that synthesis. The National Academies is a private, nonprofit institution in the US whose mission is to provide evidence-based guidance to the nation that informs policy and practice. The session provides a timely introduction to NARST members of the results of this consensus study, released in fall 2021. Several committee members (including the committee chair) and one National Academies staff member (the study director) will present the key conclusions and recommendations of the report, two discussants who are leaders in the field will provide commentary, and the session chair/presider, also a leader in the field, will facilitate a rich discussion of the global implications of the work for policy, practice, and research.

Elizabeth X. De Los Santos Candice R. Guy-Gaytán

Investigating Teachers' Professional Learning Experiences on an Assessment Development Team

This related paper set presents the results of our work developing and implementing a threedimensional district biology assessment within the context of a research-practice partnership. We include our practice partners as lead co-authors to demonstrate our commitment to valuing practice perspectives in science education. Paper 1 describes the district science curriculum coordinator's decision-making about the development of the assessment, including successes and challenges of the process. Paper 2 describes how the district implemented the assessment and used the data from administration of the assessment to all high school biology students in the district. Paper 3 investigates teachers' professional learning experiences as an item writer on the assessment development team. Finally, Paper 4 investigates students' reasoning on the assessment using a think-aloud protocol. Altogether, these four papers highlight different aspects of the development and implementation process of a district science assessment from both practice and research perspectives and contributes to our understanding of the challenges of enacting educational reforms in complex educational systems.

Vera Degtiareva Emily C. Allen

Pedagogy in practice: exploring the use of pedagogy course knowledge by learning assistants

Learning Assistants (LAs) are increasingly used in classrooms all over the globe, where LAs help teach in a variety of student-centered, active-learning environments. The LA Model consists of three pillars: the LA pedagogy course, weekly prep meetings with the instructional team, and the LA practice of working with small groups of students. In this paper, we utilize an existing framework of essential pedagogy principles identified by Top et al. to develop a coding scheme for comparing what LAs learn in the pedagogy course to what they do in their LA practice. In particular, we looked for evidence that LAs use the concepts of acknowledging student ideas, constructing knowledge, and formative assessment. We apply the coding scheme to audio recordings of ten different LAs facilitating student discussion in five separate sections of an approximately 400 person, introductory studio physics course. We found that our coding scheme can be used to demonstrate the LA use of the essential pedagogy principles. We propose that our coding scheme could be employed as a part of the LA pedagogy class to facilitate peer observations as well as a diagnostic tool that the pedagogy course instructors could use to evaluate and improve the course.

Dave Del Gobbo Sheliza Ibrahim Khan

Weaving Art & Science Pedagogies for More Ecologically-vital & Socially-just Dispositifs

Humanity is facing myriad 'wicked' problems — including those linked to climate, surveillance systems, manufactured foods, habitats and related species diversities — associated with capitalism-influenced fields of science and technology. Assuming capitalist manipulation of public knowledge and subjectivities and learners' diverse abilities, cultural and social capital, etc., the five papers in this Related Paper set provide theoretical and empirically-based evaluations of a constructivism-informed pegagogical schema (ReActions) that prioritizes direct teacher instruction of often difficult-to-discover conceptions in relationships among science and technology and societies and environments and education encouraging

and enabling students to independently implement sociopolitical actions to overcome harms like those above of their concern. The five papers appear to support Unity and Inclusion for Global Scientific Literacy through qualitative action research to apply and evaluate the ReActions schema in multiple educational contexts (primary, secondary & tertiary), drawing from Science & Technology Studies [STS]) and the arts to understand possible alignments among numerous 'actants' within a growing dispositif (i.e., purposeful machine-like actor-networks) that may promote ecojustice outcomes, like: communitycentred (vs. individualistic) goals; ecocentric (vs. anthropocentric) worldviews; tempered (vs. continuous) change; and, intrinsic (vs. exchange) values. STS conceptions apparently aiding this work include: sociotechnical imaginaries; dispositifs; phenomena-semiotic relationships; (de-)punctualization; and, governmentality.

Cesar Delgado Kathryn Green

Trajectories of Adoption and Abandonment After Professional Development in Project-Based Learning

Project-based learning (PBL) is a pedagogical approach in which students construct their own knowledge by engaging in relevant, realistic problems. Key features of PBL include a driving question to link important academic content to students' lives, inquiry and problem solving, collaboration, use of learning technologies, and the creation of tangible products. Research has demonstrated the effectiveness of PBL in secondary science classrooms. However, implementing PBL for the first time is challenging and thus professional development is essential. This paper reports on the trajectories of science teachers two years after they took a well-designed PBL PD workshop, as well as identifying the obstacles and challenges as well as supports that those teachers experienced. Trajectories identified were: Abandonment, Adoption and Expansion of Her Own Practice, Adoption and Catalyst in School, and Adoption and Catalyst Beyond the School. Critical challenges included unsupportive school environment and misunderstanding the nature of PBL. The identified trajectories of teachers constitute a useful analytical tool for future studies, while the design of the PD can serve as a model for similar efforts.

Laura Dell

Using Photovoice to Understand Children's Experiences and Environmental Science Learning at a Nature Preschool

This research project described and documented the experiences of children ages 3 to 6 attending a nature-based preschool located on a private nature preserve in the Midwestern U.S. Building on a theoretical framework that recognizes children as competent social actors who are experts in their own experiences, this project used photovoice methodology to allow children to function as both data collectors and data interpreters. Results show that children at this nature preschool valued learning about plants and animals in nature, time with friends and teachers in nature, and hiking and exploring in wild spaces. The study also provides evidence that young children are able to particpate in photovoice research protocols as experts in their own educational experiences. For schools looking to implement nature-based teaching strategies, finding neighborhood natural spaces may be more cost-effective and impactful on student relationships with nature than building large natural playgrounds or playscapes.

Hasan Deniz Erdogan Kaya

Searching for Nature of Engineering in the Framework for K-12 Science Education

In this study, we aimed to discern epistemic aspects of engineering (nature of engineering) relevant to K-12 engineering education from the Framework (NRC, 2012), and to suggest ways to teach NOE integrated with the engineering design process. We classified the epistemic aspects of engineering that we discerned from the Framework into eight nature of engineering (NOE) aspects and reported how many times each NOE aspect was mentioned in the Framework. We also made recommendations about how to teach NOE aspects in an explicit-reflective fashion while students are engaged in the engineering design process.

Ian Descamps

Using Conjecture Mapping to Uncover Sociomaterial Entanglements in Introductory Physics Labs

Learning environments designed to engage students in authentic forms of scientific practice must reflect the heterogeneous nature of disciplinary learning. Central to professional science is the active coordination of multiple threads in the practices of doing science. These organizing acts weave together the technical, social, political, and material elements of inquiry in ways that achieve shared, cultural goals. Within these sociomaterial entanglements, agency is distributed among learners, materials, and tools in ways that expand and deepen our collective sense of what it means to learn science. This session specifically examines and codifies themes relating the material natures of learning in college science courses, through shared focus on agency, computation and simulation, and disciplinary inquiry. Drawing from recent moves away from the "cookbook" and prescribed laboratory experiences, this related paper set presents four unique studies that center and explore issues of materiality in college science learning. They include (1) exploring how introductory physics instructors design for sociomaterial entanglements, (2) attention to students' trajectories of practice navigating uncertainty, (3) students' creative hacking of laboratory materials to develop models, and (4) disciplinary practices presented as a series of conversations that students have with themselves, with others, and with materials and representations.

FNU Desi Cuc Vu

Students' Sensemaking Related to Mathematical Equations in A Biology Classroom

Reforms in science and mathematics education call for an instructional shift away from rote learning toward sensemaking. However, students often struggle to engage in sensemaking related to mathematics within science and connecting mathematical equations with biological phenomena. Failure to make these connections can result in difficulties understanding science concepts and solving novel or

more complex problems. This case study investigated students' engagement in sci-math sensemaking when provided with opportunities to modify mathematical expressions to fit a more complex situation. The Sci-Math Sensemaking Framework was used to identify the types of sensemaking and the way they were organized during groups' discussion. This study found that all groups used both mathematics and science sensemaking during small group discussion. Although the task was to modify a mathematical equation, they still discussed science concepts, using science sensemaking to support mathematics sensemaking and vice versa. Documentation of the types and organization of sensemaking across groups provides guidance for future studies investigating the relationship between student problem solving and the types and organization of sensemaking within different instructional tasks.

Dennis Dietz Claus Bolte

How different approaches to science teaching influence vertical knowledge-linking within the concept of energy

In contrast to English-speaking countries (like the US), science at the secondary level in Germany is taught differentiated into the subjects biology, chemistry, and physics. According to relevant learning theories, researchers suspect a superiority of the integrated science teaching approach concerning knowledge-linking – although empirical evidence is still missing. In this study, we investigate the effects of both science teaching approaches on students' knowledge-linking performance within the concept of energy. The choice of the topic energy makes particular sense, since energy is a cross-cutting concept which is important in all science subjects. To investigate long-time effects, we examine student essays on the concept of energy in a German academic high school who received either two school years of subject-differentiated or integrated science instruction in grades 7 and 8. Since existing models for describing and analyzing vertical (intra-subject) knowledge-linking only provide limited comparable analysis results, we developed our own theory-based model based on theory to analyze content knowledge-linking in essays following Mayring's procedure of qualitative content analysis. Our analysis shows that students receiving the integrated science approach (N = 141) show more frequent as well as superior content knowledge-linking than students receiving the differentiated science approach (N = 132).

Bat-Shahar Dorfman Amir Mitchell

Experiencing the Emergence of Antibiotics Resistant Bacteria: Students' Understanding of the Nature of Evolution

The theory of evolution has been described as one of the most consistent and unifying theoretical entities in biology, capable of explaining many natural phenomena. This theory lies at the basis of several phenomena which concern global and local communities worldwide, like the emergence of antibiotics resistant bacteria. However, high-school students rarely have access to current technologies and practices used in evolution and genetics research. This may hinder students' understanding of evolution and the related phenomena. This proposal outlines a novel instructional strategy that enabled 100 high school students to experience evolution in bacteria under antibiotics pressure. Pre- and post-

program questionnaires indicate that despite a significant improvement in students' understanding of evolution and its genetic basis, some wrong ideas still prevailed, such as that mutations never disappear. This novel approach can provide opportunities to science educators and science education researchers to include students from various communities worldwide in cutting-edge evolution experiments, thus enriching their science learning experiences and promoting their understanding of evolution and genetics.

Bat-Shahar Dorfman Amir Mitchell

Cutting-edge Evolution Research Made Available to High-school Students: Assessing Students' Views of Scientific Inquiry

While technological breakthroughs have transformed biological research into a technology-driven science, K-12 students remain largely oblivious of the technologies and accompanying practices used in research today. This further deepens the gap between school-based and authentic scientific inquiry (SI), which may affect students' views on science. In this novel remote lab-evolution program 100 Israeli high-school students were engaged in a cutting-edge research focusing on a current challenge in medicine – antibiotic resistant bacteria. The students planned and applied different antibiotic regimens to E.coli by remotely operating a robotic system located in the US. We investigated how experiencing an authentic cutting-edge research influenced the students' views on SI. The students filled pre- and post-program questionnaires aimed to assess their views on SI, and feedback questionnaires in which they described their experiences. Six students were interviewed. Following the program, transitions to more informed views about SI were observed. However, many students still held naïve views. This program offers a new perspective to SI in high-school. It allows to bridge geographical distances so that students from all over the world could experience scientific inquiry's dynamic nature, to create a more complete picture of how scientific knowledge is generated.

Remy Dou Heidi Cian

Undergraduate STEM Majors' Association of K-12 Experiences with their STEM Identities

200-word abstract (186 words currently): For most children, their first association with "STEM" or "science" is in the classroom where they attend classes explicitly referenced as such. Consequently, the classroom context has tremendous influence on how children come to define the discipline of STEM and, by extension, their congruence with STEM. Drawing from social identity perspectives and understanding of recognition, interest, and performance-competence identity precursors, in this study we postulate that the actions of teachers in these explicitly defined STEM contexts affect students' self-perceptions in STEM. Drawing from retrospective interviews with current college STEM students, we demonstrate that students' interactions with their teachers influenced their interest in STEM as students associated "doing STEM" with the experiences they had in the classroom. Further, we show how classrooms created unique opportunities for positioning in STEM as students are evaluated by their teachers and interact with peers with whom they can compare their interests, performances, and recognition from the teacher. We suggest that this work has implications for how teachers think about the construction of their classrooms and the evaluatuative interactions they have with students, particularly when it comes to comparing students to peers.
Sara J. Dozier

Inequitable opportunities to learn: Frequency of inquiry-based teaching in the United States

Do all students in the United States experience inquiry-based science instruction, for example using laboratory experiments and scientific argumentation, with similar frequencies and what impact might this have on learning? Reports from the influential Programme for International Student Assessment (PISA) show that that students from higher socioeconomic strata (SES) experience inquiry less frequently than students from lower SES. This study untangles the relationship between SES, inquiry-based instruction, and science achievement in the United States. PISA reports that students from low-SES backgrounds receive less inquiry-based instruction than their high-SES peers. This study shows that not all types of "inquiry" are experienced equally. A deeper look at exactly what we mean by inquiry-based instruction shows that the PISA inquiry-based instruction index serves to obscure the relationship between inquiry and SES. PISA also reports assume a linear relationship between student-reported frequencies of inquiry-based instruction and achievement. However, this study shows that a curvilinear model better fits the data and that students from higher SES benefit more from inquiry-based instructional practices. Implications for practitioners and policymakers are discussed.

Dina Drits-Esser Ann E Lambert

Cells in Context: Comparing Online vs. In-person Delivery

We developed, pilot tested, and field tested a three-dimensional middle school cell biology unit called Cells in Context. The unit uses pathogens as a phenomenon to teach students that (a) specialized cell parts allow cells to do their jobs, and (b) cells contribute to the functions of tissues, organs, and organ systems. Students use dynamic multimedia materials to explore how pathogens disrupt function at each level of biological organization, leading to the symptoms of illnesses. Through an iterative development process, we created a 17-item multiple-choice pre/post assessment instrument to tap student mastery of unit learning objectives and DCIs. Curriculum pilot testing showed learning gains from pretest to posttest and psychometric analyses supported the assessment's validity. Following pilot testing, seven teachers and their 291 students participated in a Quasi Experimental Design (QED) field test where teachers taught the unit online or in person. With both delivery formats, students showed learning gains. Qualitative feedback showed that teachers thought the phenomenon aided student learning and that the unit provided exposure and practice with all three NGSS dimensions. Teachers can confidently use the Cells in Context unit to teach middle school cell biology both online and in-person.

Irene Drymiotou Costas P. Constantinou

Would a career in science suit me? Students' self-view in relation to science and STEM career aspirations

This multiple case study follows eight students attending an urban secondary school for five consecutive years (13-17 years old) for the purpose of exploring their self-views in relation to science and STEM career aspirations. Framed within Social Cognitive Career Theory (SCCT), this study examines the

interplay between experiences with school science, factors relating to the social and family environment, evolving self-views during adolescence, and career aspirations. Data were collected through semi-structured interviews eight times over a five-year period and were analyzed through content analysis. Triangulation was achieved through teacher interviews and access to personal and family information through the school. The findings reveal a dynamic relationship between students' self-views and career aspirations that is influenced by experiences with school science, and also extrinsic factors relating to the social context and the family environment. Gender differences, family backgrounds and expectations, engagement with science-related activities, and interest in science were found to have a critical role in shaping students' self-views, and also their career aspirations. The findings have implications for career-oriented curriculum design aiming to enhance students' selfidentification with science, improve awareness of STEM-related career options, and potentially facilitate relevant aspirations.

Ryan Dunk Jason R. Wiles

A 5-year Analysis of the Impact of Religion and Political Views on Acceptance of Evolution

Many people not only lack an understanding of evolutionary concepts but also resist accepting the theory of evolution as the best scientific explanation. Factors affecting the development of understanding and acceptance are diverse, including cognitive, affective, and contextual features. Religious identity and background are often negatively related to acceptance rates and are among the main factors for predicting whether people will accept or reject the theory of evolution. To contribute to this ongoing challenge that peoples' religious identity brings into evolution education, this related paper set combines four papers that focus on the interplay of religious identity with evolution acceptance. In the first paper, historical data were investigated to determine if acceptance patterns have changed over time based on students' religious affiliation. The second paper determined the influence of culturally competent practices on students' evolution acceptance outcomes. The authors of the third paper gathered evidence through in-depth interviews to better understand conceptions of religious people but who accept the theory of evolution. In the fourth and last paper, responses of self-identified creationists to often-used evolution acceptance measurements were collected to generate new validity evidence.

Jaclyn M. Easter Jerrid W. Kruse

Using Science Historical Short Stories to Impact Students' Science-specific and General Epistemological Beliefs

Given the barriers of learning when epistemological beliefs are more traditional, the researchers seek to examine how historical short stories with explicit and reflective questions targeting epistemological beliefs concepts may help students develop more sophisticated domain-general and domain-specific science epistemological beliefs (EBs). In this study, three teachers guided 189 8th grade science students through use of science historical short stories highlighting epistemological ideas. The students were randomly assigned by the researcher to one of two groups. The treatment group worked through two science historical short stories with embedded explicit/reflective questions about domain-general

EBs. The control group received the same stories with questions focused on science content. Students' domain-general and domain-specific science EBs were measured three times; exploratory factor analysis with principle components and varimax rotation was conducted each time, generating five factors. The students' beliefs did not improve in any of the analysis-generated factors, but did improve when measuring domain-general EBs as a whole. Despite the short treatment, students' EBs were susceptible to change, and an increase persisted at the extended posttest. However, the domain-specific beliefs did not improve. In some cases, there were statistically significant declines in the EBs of both groups. Implications and future directions are discussed.

Daniel C. Edelson Brian J. Reiser

Bringing a Science Education Research Perspective to the Development of Instructional Materials for Broad Use

In this proposal for a related paper set, the authors of the individual papers are science education researchers who are engaged in the development of instructional materials designed for broad use across the U.S. The premise of the project is that science education researchers bring a valuable set of perspectives, knowledge, and skills to this work. At the same time, the process of developing instructional materials for widespread use across the diverse school settings that are found in the U.S. has called for the participating researchers to develop new perspectives, knowledge, and skills. Throughout this paper set, we explore the challenges of bringing researcher perspectives and research-based approaches to the design of instructional materials for broad use. We do so through case studies in which we describe how we have been able to apply theory, findings from prior research, and research methods to achieve the goals of the project. We also describe how the challenges of the project have required us to go beyond the knowledge, tools, and techniques that we brought to the project, typically through collaboration with others whose understanding of science teaching and learning is rooted in other training pathways, professional experience, and personal histories.

Hadeel Omar Edrees Dabbah Orit Ben Zvi Assaraf

Identifying the seeds of productive science discourse in undergraduate courses for pre-service science teachers

Productive dialogical discourse is important to promoting meaningful learning, but many science teachers have difficulty employing it in their classrooms. One reason for this is that they themselves had little exposure to such discourse in their own college studies. Our study examined the classroom discourse in undergraduate courses for pre-service science teachers in Israel's Arab sector. Its goal was to determine the extent to which interactions in lectures are currently dialogical, and then to identify dialogical episodes that can serve as springboards for productive scientific discourse. This information could then be used to advise lecturers on how they might develop opportunities for engaging in such discourse to promote meaningful learning in their lectures. The first stage of data analysis revealed that out of over 80 hours of recorded classroom discourse, only about a quarter was invested in science-related dialogical interactions. The second stage, a thematic analysis of individual discourse episodes,

revealed preliminary, untapped potential for the development of productive discourse in the science lectures. Based on our findings, we recommend designing professional development programs in which college lecturers conduct similar reflective analyses of examples from their own lectures, learning to identify and develop opportunities for productive dialogical discourse.

Heba EL-Deghaidy

Infusing social responsibility in higher education through education for sustainable development

This paper presents contributions from 41 students enrolled at a not-for-profit higher education institution in Egypt. The paper highlights how organisations such as higher educational institutions align their values with societal expectations through educating future generations and how such institutions need to lead societal transformation through their programmes and courses, especially in a liberal arts institution. A course on education for sustainable development (ESD) was developed and offered. The course was designed based on the sociocultural theory. The theory was reflected in all course activities and assignments through student centred collaborative activities where knowledge was shared through social cultural tools and context. The course aimed at developing students' individual social responsibility (ISR) as change agents in their local contexts. This paper illustrates the main milestones and processes through a mixed methods approach of what students went through during their enrolment in a 15-week elective course on ESD. Three instruments were developed to collect quantitative and qualitative data to answer the research questions.

Glenn R. Dolphin Stanley M. Lo

Supporting and Advancing Science Education Research Practice through Community Discussions

The goal of this session is to promote innovative and rigorous research practices in science education research. Our specific objective to advance this goal is to provide methodological support for graduate students and early career scholars in their work around science education research methods. Attendees will engage in roundtable conversations about qualitative, quantitative, and mixed methods research designs. These conversations will also address framing a research project- theoretically, conceptually, and methodologically. More senior and advanced researchers will be on hand during the session to facilitate these discussions and to help provide networking support. Attendees are encouraged but not expected to bring their research related questions, problems, and ideas to discuss.

Emil Eidin Jonathan Bowers

Comparing how students' conceptual understanding and computational model explain system mechanisms in time-based phenomena

The science education community acknowledges the importance of integrating learning about complex systems and adopting a system thinking approach as part of the effort to prepare scientifically literate citizens. However, accumulating research in the past years has clearly shown that teachers and students alike face various challenges engaging in aspects of system thinking. One of the prominent challenges

includes the difficulty of addressing underlying mechanisms that account for a system's behavior. In this paper set, an international effort is made to present different tools and strategies that can serve to elicit some of the underlying mechanistic reasoning teachers and students use to make sense of complex systems. We show how system dynamics models, agent-based models, and concept maps can be used to elicit students' mechanistic reasoning and support it. Our collaborative work provides an opportunity to learn about different tools and the affordances they provide, both for characterizing mechanistic reasoning in the context of complex systems, and supporting teachers and students in making sense of complex phenomena using system thinking aspects.

Stephanie S Eldridge Georgia Hodges

Supporting Secondary Science Teachers' Awareness of Gender Variance and Creation of Gender-Inclusive Lesson Plans

Science is often taught and perceived as identity-free, a misconception that is reflected in science teachers' lesson planning. Science teacher education programs do not typically address gender-inclusive practices or prepare science teachers to support trans* and gender nonconforming (TGNC) students beyond respecting pronouns. The purpose of this study is to identify and challenge gender-based assumptions and support development of gender-inclusive practices of secondary science teachers. A total of 48 in-service and pre-service science teachers participated in an online asynchronous course that included a module focusing on gender. Research questions were: (a) What initial conceptions to science teachers hold about gender and sex in relation to the science curriculum? (b) What strategies do science teachers use when prompted to create gender-inclusive lesson plans? (c) How do science teachers' choice of gender-inclusive strategies reflect their ideas about gender? Analysis of teachers' written responses revealed the following themes: views of gender as binary, awareness of the need to support TGNC students, moving beyond representation, invisibility of gender norms, and avoidance of TGNC-related discussions. Science teachers will benefit from explicit instruction on gender-affirming language in the context of the science curriculum, intentional conversations, and examination of implicit biases around TGNC students.

Colin Hennessy Elliott

Productive tensions: Researching and imagining a more just STEM education with youth researchers

This paper set brings together seven emerging scholars and their collaborators together to explore diverse methodological, theoretical, and pedagogical approaches to support justice-oriented STEM education. Five papers will be presented that use different theoretical, methodological, and pedagogical approaches to explore working towards expanded learning opportunities with learners and their teachers. Additionally, these papers are situated with grade levels and formal/informal learning settings. After the papers are presented, the question of how can diverse research methodologies, pedagogies, and conceptual frameworks unite to support justice-oriented STEM teaching and learning? will be discussed by the presenters as well as the broader audience. The intentionally diverse topics of this

paper set will allow the NARST community to engage how multiple approaches are needed to support justice-oriented STEM teaching and learning.

Leslie Atkins Elliott

Curating Materials for Epistemic Agency

Learning environments designed to engage students in authentic forms of scientific practice must reflect the heterogeneous nature of disciplinary learning. Central to professional science is the active coordination of multiple threads in the practices of doing science. These organizing acts weave together the technical, social, political, and material elements of inquiry in ways that achieve shared, cultural goals. Within these sociomaterial entanglements, agency is distributed among learners, materials, and tools in ways that expand and deepen our collective sense of what it means to learn science. This session specifically examines and codifies themes relating the material natures of learning in college science courses, through shared focus on agency, computation and simulation, and disciplinary inquiry. Drawing from recent moves away from the "cookbook" and prescribed laboratory experiences, this related paper set presents four unique studies that center and explore issues of materiality in college science learning. They include (1) exploring how introductory physics instructors design for sociomaterial entanglements, (2) attention to students' trajectories of practice navigating uncertainty, (3) students' creative hacking of laboratory materials to develop models, and (4) disciplinary practices presented as a series of conversations that students have with themselves, with others, and with materials and representations.

Jamie Elsner Troy D Sadler

Student Interest, Concerns and Information-Seeking Behaviors Related to Covid-19

COVID-19 creates an opportunity for science classrooms to relate content about viruses to students' personal experiences with the pandemic. Previous research has shown that students are interested in crisis situations like disease outbreaks; however, they primarily acquire information about these events through internet sources that are often biased. We contend that it is essential to understand student interest, concerns, and information-seeking behaviors related to COVID-19 to support science classroom learning and engagement about the virus and other potential outbreaks. We surveyed 224 high school students and analyzed their responses to six open-ended questions. We found that students expressed the most interest in topics related to the origin of COVID-19 and vaccines. Their greatest concerns included contracting the virus, someone they know contracting the virus, and vaccine distribution. Of our sample, only 6.7% reported using their teachers as their source of COVID-19 information. Science classrooms have the potential to peak students' situational interest by discussing COVID-19 topics that are important to students, which can increase their academic performance, content knowledge, attention, and engagement in learning about viruses. We provide key areas of student interest about COVID-19 to help educators address students' questions and improve curricular resources on viral pandemics.

Markus Emden Arne Bewersdorff

Developing Science Teachers Professional Competence in Opened Experimentation – An Intervention Study

The proposal introduces a quasi-experimental study in the context of secondary science teacher professional development (PD). Forty-six secondary science teachers (grades 5–10; student ages 10–16) took part in one of two formats PD on inquiry-based teaching through an innovative approach to Opened Experimentation. Design of the PD used a theoretical framework derived from international research specifying five key features of effective PD. The PD formats varied the encouraged degree of Active Learning for participants. Teachers' developments in three crucial aspects of professional competence were surveyed with tests, questionnaires, and videography: Professional Content Knowledge (PCK) on experimentation, beliefs towards experimentation, classroom practice on experimentation. The program proved to be effective with regard to improving teachers' beliefs and classroom practice – the latter of which is subject of a separate proposal and, thus, will not be discussed in detail here. Evidence for an increase in experiment-related PCK appears to be limited but still served to show that teachers' needed (and received) development with regard to fundamental declarative content (What is an experiment? How does an experiment unfold?). An hypothesized superiority of an elevated degree of Active Learning through intensified collaboration cannot be maintained.

Uchenna Emenaha

The new four-letter word, 'race': Exploring Teacher Positions within biology education and critical race theory.

The aspects that makeup teacher positionality are essential in understanding why teachers make the curriculum decisions they make and make shifts in limiting ideologies towards the advancement of the science curriculum. Teachers cannot leave part of who they are at home, but rather bring the entirety of who they are into their teaching practices, even in "non-subjective" courses like science. Exploring the dynamic role of teachers' experiences that shape their positionality can provide insight into what factors can better support teachers in approaching misconceptions and stereotypes about race and human diversity. The topic of race can be viewed as controversial; however, this should not deter the discussion of the subject within the classroom. To truly develop students' sociopolitical consciousness, relevant research supports the use of critical race theory (CRT) to explain the gaps in biology instruction on race and human diversity. A scientifically accurate understating of race and human diversity can debunk racial stereotypes, provide further context and awareness of larger systems outside of the biology curriculum that promotes racial stereotypes and biased ideologies.

Lauren N. Emery

Using Redirections to Examine Responsiveness to Student Thinking in Secondary Science Classrooms

The Next Generation Science Standards have invigorated a push towards the expectation that students should engage in science as scientists do. This requires teachers to have the skills necessary to engage with their students' science ideas. This study draws from the construct of responsive teaching. Responsive teaching includes; 1) attention to students' ideas, 2) drawing disciplinary connections between student ideas, and 3) taking up and pursuing students' thinking (Robertson et al., 2016). The current study takes place in the context of a larger study, five-year professional development program. This program had an explicit focus on students' mathematics and science ideas. Classroom video was collected annually from each teacher, and discourse analysis was used to examine three teachers' responsiveness to student thinking. I specifically used and adapted Lineback's (2014) redirections coding framework. A redirection is a teacher's bid to shift the focus or activity of the class. New redirections identified in my study were shifts in activity, unresponsive to student thinking. These included;1) whole class discussion, 2) developing/revising explanations/models, 3) surface level tasks, 4) small groups/partner discussions, and 5) conducting observations/investigations. The redirections framework supported understanding how teachers shift in their responsiveness over time, and across participants.

Patrick J. Enderle Claudia Hagan

Tools for Observing Productive Talk: A Comparison of Two Protocols (RTOP/IQA-SOR)

As part of a larger study focused on supporting high school biology teachers' use of productive science talk, this study compares the use of two different observation protocols, the RTOP and the IQA-SOR. Reviewing a year-long data set of video observations collected from classrooms of teachers participating in the larger professional development study, the two validated instruments produced significantly correlated scores of different scales based on the unique structure of each tool. We posit this demonstrates that both instruments can be useful for analyzing classroom instruction intended to emphasize productive science talk. However, the instruments do possess unique structural and theoretical qualities that warrant this study to understand the insights afforded by each. The similarities and differences emerging from each are explored in the presentation and how they impact the analyses. These considerations can be helpful for scholars who research in-service teacher learning as classroom implementation and impact on student learning activities are general outcomes that most professional development research endeavors to explore. Further, considerations of what particular observation protocols' foci include or exclude are necessary so that continued research on teacher learning works to make science learning through discourse accessible to all learners.

Paul Engelschalt Tom Bielik

Investigating Pre-service Science Teachers' Modeling Metaknowledge with Open-Ended Questions and Diagrams

The development of modeling meta knowledge is important in pre-service science teachers' (PSTs) education. Aiming to foster PSTs MMK, its diagnosis becomes relevant. This is commonly done by openended questions assessing levels of distinct aspects of MMK but lacking to indicate PSTs' holistic MMK about the iterative nature of the modeling process. Therefore, a diagramming task was developed to evaluate PSTs' procedural components of MMK in a holistic manner. Due to being a novel method, there is not much evidence about valid interpretations for the diagramming tasks' results. Aiming to gain validity evidence, we diagnosed MMK 40 PSTs' by applying the open-ended questions and the diagramming task. A significant moderate correlation was found between the open-ended questions overall diagramming score (r=.42, p<.05) supporting the argument of valid interpretations for assessing PSTs' MMK through the diagramming task. On the other hand, no correlations were found for some of the instruments' sub scores. This may support that diagramming is more likely to assess holistic knowledge about the iterative nature of the modeling process whereas the open-ended questions assess the scientific elaboration for distinct aspects of MMK. Thus, this study contributes to PSTs education by providing valid interpretations of two methods to assess MMK.

Megan Ennes Amanda Wagner-Pelkey

Online Learning in Museums One Year after COVID-19 Closures

In 2020, 90% of museums around the world closed due to COVID-19. During this time, many museums transitioned their programs online. This study examined how museums were developing and facilitating online programs one year after COVID-19 closures. The survey was completed by 90 museum professionals engaged in online learning. The majority of programs were designed using teleconferencing software for school-based audiences, particularly for students in kindergarten through fifth grade. The results are then compared to those of a previous study conducted immediately before and after COVID-19 museum closures. The findings indicate that programs being designed and facilitated one year post COVID-19 closures more closely resemble programs designed pre-COVID, suggesting museums have had time to respond to the pandemic. This study concludes with insights and recommendations from the participants, as well as additional considerations for the future of museum-based online programming.

Duygu Yilmaz Ergul Mehmet F. Tasar

Science Teaching Orientations of Pre-Service Teachers in a Transformative Learning Environment

It is a common view that beliefs are an essential factor in teachers' technology integration efforts. Our study aims to develop pre-service science teachers' beliefs about science teaching and learning and goals and purposes of science teaching in a transformative learning environment. In the transformative learning intervention, there was a process in which the participants worked together with their critical friends to the activities prepared following the components of transformative learning: a) fear and uncertainty, b) testing and exploring, c) affirming and connecting. During the 14 weeks, data were collected from interviews, recordings of card-sorting task performances, video-recorded lessons, and participants' lesson plans. The results provide an insight into how the pre-service science teaching in the transformative learning environment. In this multiple case study we found that the four pre-service science teachers' discourses and their experiences in the classroom were incompatible with their beliefs.

Allison M. Esparza

Campus Association as a Predictor of Science Standard Evaluation using Multinomial Logistic Regression

Instructional policy reform initiatives depend on classroom teacher's ability to make sense of the policy and implement it successfully as policymakers designed. Numerous factors play a role in teacher's perception of standards including experience, gender, and grade level. To ensure the successful implementation of policies, teacher feedback should be evaluated during the review and development process. The state of Texas began its science standard review process with the release of the Survey for Science TEKS in December 2019. Stakeholders in Texas science education were asked to evaluate the current science standards, specifically, the extent to which the current Texas Essential Knowledge and Skills (TEKS) engaged students in science and engineering practices, crosscutting concepts, and the disciplinary core ideas. The author investigated the survey results from classroom teachers at three campus associations: Elementary, middle, and high school.

Mohammed Estaiteyeh Isha DeCoito

Enhancing STEM Teacher Candidates' Understanding and Implementation of Equity, Diversity, and Inclusion Through Differentiated Instruction

Differentiated instruction (DI) is a teaching approach that addresses learning for students of diverse backgrounds, abilities, and interests. This study explores STEM teacher candidates' (TCs') preparation to implement DI in a STEM curriculum and pedagogy course in a teacher education program at a Canadian university. The course is enriched with DI resources and training focused on equity, diversity, and inclusion. The course efficacy in enhancing TCs' knowledge of DI is explored through the following research questions: 1) What is the impact of the course on TCs' views, understanding, and implementation of DI? 2) Which of the course components were most effective in this regard? and 3) How do TCs develop and implement curriculum that is inclusive of DI strategies? The study adopts a mixed method approach, in which data sources include pre-post questionnaires, semi-structured interviews, and TCs' course work. Findings suggest that the course resulted in a notable improvement in TCs' DI views and pedagogical strategies. This reiterates the importance of opportunities aimed at enhancing teachers' preparation to integrate DI in their practices. This research equips teachers with practical tools and informs teacher educators and educational researchers about PD initiatives that are aimed at inclusive education.

Ayca K Fackler

A Case of Revealing Preservice Elementary Science Teachers' Understanding of Models and Modeling Through Reflections

Most teachers lack comprehensive knowledge and skills to build models in order to support their students' science learning. Adopting a case-based pedagogy approach, this case study aimed to reveal preservice elementary science teachers' understanding of models and modeling through reflective

practices in the context of a modeling workshop. Participants included 21 preservice elementary science teachers enrolled in a science methods course for elementary education at a large public university in the southeastern United States. The data sources consisted of video and audio recordings of the modeling workshop that is part of the science methods course and students' reflective responses to the modeling case. Through an inductive approach, a constant comparison analysis was employed to compare students' reflective responses. The findings suggested that preservice science teachers' understanding of what models are or are not revolves around the following three categories: models as multimodal tools, models as means to facilitate embedded ways of thinking, and models: moving beyond copies of reality.

Ayca K. Fackler

When Multimodality Meets Modeling: A Case Study of Preservice Elementary Teachers Building Knowledge in Science

Science learning requires learners to use their diverse linguistic resources in addition to the scientific language to build knowledge. Knowledge-building in science is closely related to the types of modalities used in learning environments. Multimodality embedded in modeling has the potential to enhance students' knowledge-building experience through constant shifts in meanings. Grounded in the Semantics dimension of the Legitimation Code Theory, this case study examined how multimodality embedded in modeling can facilitate packing and unpacking meanings in science learning. Data sources were audio and video recordings that captured the modeling instruction and student interviews along with student artifacts. A Multimodal Interaction Analysis suggested that students pack and unpack meanings while learning science with multimodality embedded in modeling by: engaging with materials, generating semantic expressions, and explaining what is grounded in different modalities. This study showed the potential utility of multimodality embedded in modeling by showing how student engagement in science can be examined in terms of enacted and embodied intra-actions with material–environment–students–(para)linguistic resources.

Nannan Fan

6th-graders' decision-making and informal reasoning about de-extinction

Abstract This study explores how 6th-graders in China make and justify a decision about a science textbook related socioscientific issue. Participants included 270 6th-graders who read a news article about opposing ideas on de-extinction and were asked their opinions and reasons of whether or not to support reviving extinct animals with genetic technologies. The written questionnaires were analyzed with a SEE-SEP model, focusing on the knowledge, experience, and values 6th-graders used and how they deployed these resources in their arguments. The results indicate that participants were able to justify their decision from multiple perspectives and tended to frame de-extinction as an ecological and environmental issue. Surprisingly, personal experience was barely used in students' written arguments, except for sci-fi movies like Jurassic World. The results are discussed from students' science learning experience, habits, and science practical epistemology.

Cláudia Faria Elsa Guilherme

The Portuguese Maritime Voyages: the exploration of the history of a city with an App

In this paper we present an evaluation of an App for mobile devices, 'Roteiro dos Descobrimentos', as an educational digital resource for primary school students. The study involved the participation of 131 students and eight teachers. Data were collected from participant observation, students' questionnaires and interviews to students and teachers. According to students, they learned new things, related with the topics explored, in an easy and funny way. Students also emphasized as positive aspects the fact that they had to face different challenges and the need to mobilize their knowledge to solve them. Teachers referred that students showed great interest and enthusiasm during the activities. As main gains, teachers stressed that the application fosters the relationship of students with the city, facilitates collaboration, and promotes students' autonomy. In resume, it seems that the playful and interactive dimension of the App promoted the development of important skills such as the ability to interact with the environment, collaborative work, autonomy, and reading and interpretation skills. As a conclusion, there is a great receptivity to integrate mobile technologies in the teaching and learning process, but the role of the teacher can't be dismissed, as a mediator and educator.

Farah Faruqi Khomson Keratithamkul

Manifestations of Integration in Practice: A Case Study of Three Elementary Teachers' Integration of Engineering and Science

Despite its presence in policy documents and classrooms, defining integrated STEM education has been a challenge, delaying the development of observation protocols to understand how STEM education is being practiced in K-12 classrooms. Our work uses a new 10-item observation protocol designed for integrated STEM teaching in K-12 science and engineering classrooms. Using a database of over 2000 video-recorded classroom observations of integrated STEM instruction, this related paper set provides new research that allows the project team to begin to assess and understand current methods of implementation of integrated STEM in K-12 science classrooms. This related paper set includes a series of four studies that highlights how the new observation protocol can be used to understand current classroom practice as it relates to current reform efforts, including comparisons across different classrooms, explorations related to the nature of integration, and the importance of mathematics integration. Our findings suggest that there is much work to be done related to K-12 integrated STEM instruction. The collective knowledge gained from this work can help researchers and teacher educators design professional development for in- and pre-service science teachers to support them in their efforts towards successfully integrating STEM to meet current science education reform efforts.

Sarah J. Fick Stephany RunningHawk Johnson

Preservice Elementary Teachers' Recognition of Resources Students Bring to Science Learning

Contemporary reforms in science education emphasize the importance of supporting equitable sensemaking through privileging ways of knowing science that honors students' ideas, experiences, and

community resources. Recognizing the challenge of learning to do this work, this paper set investigates how elementary preservice teachers (PSTs) can learn the knowledge and practices that facilitate more equitable learning opportunities. Paper 1 examines PSTs' engagement in equitable sensemaking of local phenomena as learners and how the PSTs discuss using local resources to engage students in making sense of local problems. Paper 2 focuses on PSTs' subject matter knowledge required for noticing and using students' ideas in equitable ways. Paper 3 examines how PSTs' thinking about how to leverage students' ideas and resources change over the course of a semester. Paper 4 investigates how PSTs noticed opportunities for promoting equitable sensemaking within their enacted lesson plans. By focusing on different elements involved in learning to support equitable sensemaking, this paper set illuminates the complexity of this work, and thus, the multiple dimensions that require consideration in elementary education. The findings have implications for teacher educators and curriculum developers working to prepare teachers to develop the practices and dispositions that move toward more equitable teaching.

Daniela Fiedler M. Elizabeth Barnes

The Influence of Religious Identity in Evolution Education - An Introduction to the Related Paper Set

Many people not only lack an understanding of evolutionary concepts but also resist accepting the theory of evolution as the best scientific explanation. Factors affecting the development of understanding and acceptance are diverse, including cognitive, affective, and contextual features. Religious identity and background are often negatively related to acceptance rates and are among the main factors for predicting whether people will accept or reject the theory of evolution. To contribute to this ongoing challenge that peoples' religious identity brings into evolution education, this related paper set combines four papers that focus on the interplay of religious identity with evolution acceptance. In the first paper, historical data were investigated to determine if acceptance patterns have changed over time based on students' religious affiliation. The second paper determined the influence of culturally competent practices on students' evolution acceptance outcomes. The authors of the third paper gathered evidence through in-depth interviews to better understand conceptions of religious people but who accept the theory of evolution. In the fourth and last paper, responses of self-identified creationists to often-used evolution acceptance measurements were collected to generate new validity evidence.

Daniela Fiedler

Factors Influencing Evolution Acceptance: A Systematic Literature Review and Meta-Analysis

Over the past decades, a large body of work has measured and examined peoples' acceptance of evolution and its relationship to various cognitive, affective, and contextual factors. There exists some attempts or reviews summarizing existing research on factors influencing evolution acceptance. Yet, these reviews seldom provide statistical outcomes or lack a systematic methodology. Hence, a systematic (statistical) summary of previous studies remains missing. Thus, the overall aim of this study is to examine the existing published literature for qualitative and quantitative evidence that explore factors influencing evolution acceptance or its development. A systematic literature review was conducted by searching three databases representing disciplines of science and education as well as one

journal that was of particular interest due to its educational focus. Search terms and criteria were defined to generate an initial database. The searches resulted in N = 696 publications, of which n = 292 were eliminated due to duplication records and n = 202 due to non-fitting eligibility reasons. As a result, n = 194 articles were obtained for assessing an in-depth review and later meta-analysis. The results of these analyses will be presented and discussed at the NARST 2022 conference.

Julian A. Fischer Tatjana Steinmann

The effect of in-person vs. distance learning on the quality of students' learning

Due to school closures in the COVID-19 pandemic, teachers and students faced the new challenge of distance learning. Since little is known about students' quality of learning in the transition from inperson to distance learning, many teachers and the broader public feared a negatively affection on students' quality of learning in distance learning. To address the hypothesis, we analyzed students' quality of learning in a short unit about energy transformation implemented in a learning management system in German physics education. The unit concerning the driving question "Why does a laptop sometimes get hot?" was used by five teachers in seven classes with N=183 students in in-person and distance learning. We measured students' quality of learning, motivation and pre knowledge. The results indicate great disparities between in-person and distance learning. Especially in distance learning, students split in different learning profiles based on their pre knowledge. The results support the importance of supporting the teacher in the transition from in-person to distance learning to address all student needs.

Vanessa Fischer Bianca Schindeldecker

Analysis of the Interplay between Study Satisfaction, Content Knowledge and Drop-out Intention in Chemistry Studies

Among other things, drop-out rates are a predictor of the output efficiency of higher education, so the investigation of the reasons for dropping out of university studies is of great importance. However, subject-specific analyses usually only take general variables into account, while the development of content knowledge is usually not considered in detail. The aim of the project presented is, based on the model of Heublein et al (2017), the investigation of subject-specific factors influencing drop-out of studies at universities in a longitudinal design. The study comprises the first two semesters of chemistry studies at two types of universities. The results indicate that the satisfaction with the study content plays a major role, followed by prior content knowledge and knowledge acquisition in the first semester. Students with low satisfaction show a higher intention to drop-out and vice versa. Based on the results, intervention measures can be derived.

Miranda S. Fitzgerald Tingting Li

Teacher change of practice during Project-based science learning enactment: Case studies across diverse contexts.

This poster session uses case studies to illustrate the day-to-day changes in classroom practices that created the positive results of a large scale efficacy study (Authors, in press). The research project spanned three universities, two states, and involved 46 schools with 2371 students and demonstrated that students develop science knowledge and social emotional learning with the intervention of project-based learning curriculum and professional learning. However, large scale research obfuscates the teacher and classroom shifts that engender this result. The case studies provide insights from diverse districts to explore (a) challenges that schools face during enactment, (b) day-to-day shifts in classrooms and, (c) teachers' efforts to adjust the curriculum to align with other initiatives.

Fernando Flores-Camacho Leticia Gallegos-Cázares

Structuralist or inferential: Which better helps to understand children comprehension of scientific representations?

This work shows an analysis of construction and interpretations of scientific representations in primary students about the day and night process. The goal is to show how the structuralist conceptions of scientific representations, based on the intuition that exists some similitude between representations and reality, do not help to understand the diversity of representations made by children and by the contrary, how the inferential conception of scientific representations provides analytical elements to understand student's ideas. The analysis shows how the structuralist conception, implicit or explicit in the teachers, forced the students to make some correspondence with reality even if they do not have the elements, abstract or experiential, to understand those representations. This situation is exemplified with the sun-Earth-moon system representation, usually used in school, to explain the day and night process in which student is denoting objects as describing reality, but without coordinating them with the natural process. From the same example, the analytical elements of the inferential conception like intentionality, interpretation, surrogate reasoning, and coordination rules are used to provide a more fructify approach to understand how children use representations and make inferences with them.

Elizabeth Forde Latanya Robinson

Yes, Math is There, but ...: Examining Mathematical Content in Integrated STEM

Despite its presence in policy documents and classrooms, defining integrated STEM education has been a challenge, delaying the development of observation protocols to understand how STEM education is being practiced in K-12 classrooms. Our work uses a new 10-item observation protocol designed for integrated STEM teaching in K-12 science and engineering classrooms. Using a database of over 2000 video-recorded classroom observations of integrated STEM instruction, this related paper set provides new research that allows the project team to begin to assess and understand current methods of implementation of integrated STEM in K-12 science classrooms. This related paper set includes a series of four studies that highlights how the new observation protocol can be used to understand current classroom practice as it relates to current reform efforts, including comparisons across different classrooms, explorations related to the nature of integration, and the importance of mathematics integration. Our findings suggest that there is much work to be done related to K-12 integrated STEM instruction. The collective knowledge gained from this work can help researchers and teacher educators design professional development for in- and pre-service science teachers to support them in their efforts towards successfully integrating STEM to meet current science education reform efforts.

David L. Fortus Jing Lin

Shifting to Distance Learning of Science in China and Israel: A Comparative Study of Students and Teachers

With the outbreak of the COVID-19 pandemic, science teachers were often required to shift from faceto-face (F2F) instruction to distance learning (DL). Using an achievement goal perspective, this study investigated the shifts that occurred in two different countries – China and Israel – in 8th grade students' motivation for science, in their perceptions of their science teachers' motivational practices, and in the relations between them, to give perspective on how local conditions may have shaped the transition from F2F instruction to DL, and help teachers and students learn how to negotiate such transitions in the future, given their local context. Over 2000 Chinese and Israeli students, who studied with the same science teachers during F2F and DL, and whose teachers had a reputation of fostering their students motivation, completed a motivation survey. Exploratory factor analysis, paired t-tests and multiple regression were used to identify trends and relations. Teachers' attentiveness to their students' need to understand, which was the major predictor of students' mastery orientation towards science in both F2F instruction and DL, for students in both countries, declined during the shift from F2F to DL, leading to a decline in students' mastery orientation, engagement and enjoyment.

Alyssa Freeman Angela Google

Biology Teaching Assistants Engagement with Educative Curriculum Materials and Enactment of Rigorous Classroom Discourse

Teaching assistants (TAs) are often responsible for the instruction of science labs associated with largeenrollment introductory courses that are important to recruit and retain science majors. However, TAs are typically in unique positions where they have limited knowledge of pedagogy. Due to the crucial role of TAs, they should be provided with adequate supports to meet instructional goals and promote an equitable learning environment for all students. One way of accomplishing this is to provide TAs with educative curriculum materials for an ambitiously designed curriculum that is integrated into a program of professional development. This research focuses on four case studies of TAs who were tasked with implementing features of ambitious science instruction in a biology lab course. In the context of an ambitious curriculum and educative supports, we examined how TAs engaged with the educative supports and how TA engagement related to their enactment of the lab curriculum. We found that as the semester progressed, TAs made fewer annotations than expected in their curriculum materials, however more rigorous contributions were made by students by the end of the semester than was expected.

Kristina Fricke Bianca Reinisch

Evaluation of Nature of Science Representations in Biology School Textbooks Using the Family Resemblance Approach

The evaluation of nature of science (NOS) representations in biology school textbooks contributes to expanding the understanding of how NOS content is presented in science class and to derive implications for the design and implementation of such content in future textbooks. In this study, four chapters of each seven biology school textbooks for secondary education level were analyzed by using an established scoring rubric and a previous developed category system based on the family resemblance approach (FRA) to NOS, which differentiates 11 main categories into 55 subcategories. Thus, the distribution and quality of NOS representations were evaluated for each subcategory across the considered chapters. The distribution of NOS representations resulted from comparing the number of NOS relevant textbook elements for each of the subcategories. The quality of NOS representations was evaluated by the manner (explicit/implicit) and the adequacy (informed/naïve and consistent/conflicting) of relevant textbook elements. Results show a varying distribution of NOS contents across the chapters, which leads to the assumption that certain subdisciplines of biology possibly correlate with certain FRA (sub-)categories. Explicit NOS representations, which are primarily placed in the introduction sections, appear to be a useful basis for the design of explicit representations in the content related chapters.

Gunnar Friege Ingmar Schneider

Teaching and Learning Kinematics: A Comparison of two Approaches

Mechanics is considered an important part of school physics and also difficult to learn. There are different approaches to teach mechanics worldwide. The two dynamic approaches 1D (study of motions in 1 dimension only) and 2D (study of motions in two dimensions) were investigated in a computer-based learning environment with interactive simulations and feedback in an empirical field study (N=275, 7th/8th grade). Both approaches can be well justified from a didactic point of view. A Rasch-scaled achievement test was used to precisely measure learning gains. Among other findings, the learning efficacy of both approaches, a higher learning efficacy for students with low prior knowledge and a positive effect on affective characteristics for female students as well as an overall low cognitive load due to the simulations used could be shown.

Travis T. Fuchs Anthony Clarke

Professional Development Principles to Advance Socio-scientific Issue-oriented Science Education: The Case of British Columbia.

The world faces many challenges that generate new possibilities for science education. One prospect that has become more pressing in recent years is that school science should prepare students to critically understand and potentially address socio-scientific issues (SSI) that affect our lives and the

environment. Though detailing teachers' motivation to enact these goals for science education is increasing, research exploring the professional development conditions necessary to support its effective enactment and teacher-accounts detailing its actualization in classrooms, remains sparse. The purpose of this research is to add to literature supporting science teachers in implementing critically minded, community-oriented, and SSI-driven goals for science education. Questions that guided the study were: (1) How do features of a professional development program based on teacher inquiry enable British Columbian science teachers to successfully respond to SSI-oriented curricular reform in their classrooms? (2) What pedagogical strategies do the teachers feel should be carried forward into future SSI-oriented planning and teaching? Significant features included the formation of a practice-oriented learning community and the use of a theoretical framework to scaffold the sense-making and articulation of pedagogical decisions. Leveraging controversy and fostering empathy were seen as important strategies. Implications for future professional development are discussed.

Katerina P. Günter Carolina De Barros Vidor

What is the Science when Talking Science Identity? Reflections from a Higher Education Biology Perspective.

Higher Education Biology (HEB) is one of the few natural sciences that are female biased on undergraduate level in e.g. Sweden and the US. While in Sweden more than 60% of biology undergraduate students are women, we find less than 30% full women professors. This female undergraduate bias has led to the assumption that gender (in)equalities are absent, but gender-neutral discourses rather deny the disadvantaging of women and minority group, making gendered in(ex)clusion processes invisible. In this proposed paper, we use the findings of the first author's PhD thesis on HEB students and teachers' identity work to address the gap of research done on worlds, landscapes, and cultures of HEB. We first contextualize HEB and suggest a biology paradox from a feminist critique of science perspective. Subsequently, we summarize and reflect on the current findings of the PhD thesis and discuss these reflections in connection to the doing, being, and knowing of Science. This not only allows for reflections on the relationship between Science and biology but also problematizes taken-forgranted ideas about Science in concepts such as science identity, suggesting a need to be more reflexive to avoid reproducing the very norms that we aim to dismantle.

Fabien Güth Helena Van Vorst

Investigating students' context choice in chemistry education

A well-known strategy to deal with heterogeneity in the classroom is called differentiated instruction. While the results of performance-based differentiation in chemistry education mostly do not show significant effects, research results on context-based learning indicate the potential of interest-based differentiation through contextual tasks with systematically varied characteristics. However, it is unclear which groups of students benefit from which contexts. The goal of this study is to identify groups of students that differ in terms of their context choice and to investigate how these students evaluate their choice after working on a context-based task in chemistry. For this purpose, a questionnaire study has been conducted with 495 third-year learners in chemistry in secondary schools. Through a cluster analysis based on individual student characteristics, four groups of students could be identified that show preferences at contexts with different characteristics. The results will be used for interest-based differentiation with the help of systematically varied contextual tasks.

Rivka Gadot Dina Tsybulsky

Digital Curation as a Pedagogical Approach Promoting Critical Thinking

This study is about Digital Curation (DC) as a practice that involves the essential actions of scientists today and can be used as a pedagogical approach that engages students with the necessary skills for scientists in particular and citizens in general in the current era. The study is of quantitative approach. The two research questions that this study sought to answer were: QR1: Is and in what way is DC a pedagogical approach that requires critical thinking? QR2: What factors affect DC activity? The participants were undergraduate and graduate students (n=94) from universities in Israel. The students were required as part of their course assignments to build a digital collection. Data collection was twofold: 1. log files of the digital collections' creation activity; 2. content analysis of the digital collections. We analyzed the data in two phases: (1) based on preliminary research we coded the data. Then, (2) statistical analysis of the data was obtained. The findings of the study revealed that DC indeed provides a beneficial learning activity that supports critical thinking.

Jessica Gale Meltem Alemdar

Exploring The Sources of Science Teachers' Self-Efficacy

Although teaching self-efficacy is associated with many benefits for teachers and students, little is known about how science teachers develop a sense of efficacy in the early years of their careers. Drawing on survey (N=179) and interview (N=7) data, this study investigates the sources of self-efficacy in a national sample of STEM teachers who participated in the Noyce program. All teachers completed an online survey that included the Teacher Sense of Efficacy Instrument and open-ended items prompting them to reflect on the sources of their self-efficacy. Seven science teachers participated in semi-structured follow-up interviews. Enactive mastery experiences were the most common source of self-efficacy identified by science teachers; however, science teachers were significantly more likely to identify negative enactive experiences that lowered their self-efficacy than math teachers. Open-ended survey responses and interview data suggest that many of these early negative experiences stem from out-of-field teaching assignments and/or frequent shifts in grade-level or disciplinary teaching context. Additionally, teacher narratives described how the sources of self-efficacy combined or interacted to influence science teaching self-efficacy. Findings contribute to better understandings of the sources of self-efficacy with implications for how best to support science teachers at different stages of their careers.

John Galisky Matthew D. Bennett

Planning vs. Instruction: Analysis of Preservice Secondary Science Teachers' Use of Practices and Crosscutting Concepts

The Next Generation Science Standards require that all students not only learn science content but also think like scientists as they engage in activities to explore real-world phenomena. In this study, we investigated preservice secondary science teachers' planning and implementation of two of the three dimensions of the NGSS used to support student sensemaking: Science and Engineering Practices, and Crosscutting Concepts. We qualitatively analyzed 11 participants' edTPA (teacher performance assessment) portfolios for their planning and implementation of the CCCs and SEPs. We found that preservice teachers' engagement of students in the SEPs appeared to occur organically: During their edTPA lesson sequence, both SEPs explicitly planned for and those not explicitly planned for became evident in their instruction. We also found, however, that the CCCs required explicit planning in order for them to be visible during instruction. Indeed, preservice teachers sometimes explicitly planned for CCCs that failed to emerge during their instruction. In our discussion, we argue for the importance of teacher education programs and cooperating teachers providing preservice teachers with more coaching and more opportunities to learn about and practice with the CCCs so that all students can participate in the science sensemaking envisioned by the NGSS.

Grant E. Gardner Olena T James

Faculty Awareness and Responsiveness to Inclusivity in STEM Classrooms

In STEM disciplines at the undergraduate level there is an underrepresentation of diverse groups in the classroom. There is a global shift to more inclusive classroom environments in STEM education. Universities can help promote STEM faculty awareness and implementation of inclusive practices with training programs and ongoing support. We describe the experiences of STEM faculty in the early phase of a year-long inclusive pedagogy profressional development program. The professional development was designed as a Faculty Learning Community (FLC) and focused on raising awareness of meeting the needs of a diverse student population in STEM and inclusive pedagogy. The FLC met for whole-group and small-group discussions. Using a Case Study Research Design, semi-structured interviews were used to help answer one research questions: What are STEM faculty participants focused upon when reflecting on inclusive pedagogy early in the PD? The interviews were conducted in the beginning of the professional development. We will discuss STEM faculty perceptions and practices related to inclusive pedagogy. We will do this through highlighting aspects from the Concepts of Diversity Framework through which instructors' experiences were similar to the Framework descriptors.

Carola Garrecht Nina Christenson

The Role of Risk Perception for Students' Climate-Friendly Intentions to Act

Several studies show that students often lack conceptual knowledge and show multiple misconceptions when explaining climate change (Boyes & Stanisstreet, 1993; Flener-Lovitt, 2014; Shepardson et al., 2011). Hence, it is often argued that science education should focus on conveying sufficient conceptual knowledge about climate change, its causes, consequences, and potential ways of adaptation and mitigation. However, besides scientific content knowledge, decision-making and the intention to act in a

climate-friendly manner seem also to be influenced by non-scientific factors such as attitudes and value attribution (Dietz, Dan, & Shwom, 2007). The USGCRP (2009) thus promotes to focus education on climate literacy, which includes specific knowledge about climate change, as well as skills and attitudes relevant to the topic. So far, studies examining the impact of climate literacy on actual decision-making are scarce, and the general picture about other factors that contribute to young learners' conceptions of climate change – including the media, family, peers, but also emotional attachment and risk perception – remains somewhat unclear. In this related paper set, we aim to elaborate how climate literacy can be modelled and assessed, how it can be promoted through meaningful instruction, and how teacher professional development can contribute to this.

Jennifer A. Gatz Angela M. Kelly

Influence of Active Goals on Attitudes, Intentions, and Academic Behaviors of STEM Women in an Undergraduate Peer Mentoring Program

Motivation starts with intention to perform certain behaviors to achieve and meet expectations. An understanding of behavioral determinants can provide a basis for designing and improving interventions to increase retention of women in STEM majors. This qualitative study examined the intentions, attitudes, and behavioral effects of a formal peer mentoring program on the social and academic integration of N = 18 female members of the Women in Science and Engineering (WISE) Honors program at a large Northeastern university. The study explored impacts of a formal mentoring program on goal setting, motivation, and persistence. A phenomenological approach was employed with elements of grounded theory to analyze data from open ended items on a survey for insights into programmatic outcomes. Qualitative analysis revealed that active goals such as a getting a good well-paying job, having fun, and help with my major influenced attitudes and motivation towards peer mentoring and intentions towards networking and research opportunities to advance the academic achievement of the first-year women mentees. Participation furthered several active goals simultaneously leading to increased academic and social integration and opportunity for first-year women in STEM majors. Implications for designing peer mentoring programs for undergraduate women in STEM are discussed.

Olasunkanmi Adio Gbeleyi Peter A. Okebukola

Heartbreak for Underachievement: Perspectives of CTCA on Students' Achievement and Critical Thinking in Computer Studies

This study employed a survey and quasi-experimental design. The purpose of this study is to find out the efficacy of culturo-techno-contextual approach (CTCA), and Gbeleyi 1.0 on students' achievement and critical thinking skills in logic gate. Results obtained from the survey in the first phase revealed logic gate, problem-solving skills, and machine language as the most difficult topic in computer studies new curriculum. The second phase was guided by two research questions with three public junior secondary (equivalent of 7th grade) in Lagos State, Nigeria. About 38% of the respondents were males while about 62% were females. Logic gate achievement test (LGAT), critical thinking skills task (CTST), and an interview guide were used to collect data for the study. The data gathered was subjected to multivariate analysis of covariate (MANCOVA), the results revealed a statistically significant difference in the

methods used, multivariate F (Pillai's Trace) was significant [F=17.67; p<.05], univariate ANOVA on achievement [F (2, 208) = 20.67; p<0.05]; and critical thinking skills [F (2, 208) = 15.14; p<0.05]. Within the scope of the study, it was tentatively recommended that CTCA should be adopted by computer studies instructors in teaching-learning in secondary schools.

Frikkie George Keith R. Langenhoven

Using an Adaptive Learning System Teaching Engineering Students: Challenges and Opportunities

Paper-based textbooks and assessments remain the primary resource of teaching, learning, and assessment. The national lockdown caused by the COVID-19 pandemic resulted in students having limited access to libraries and textbooks, and the concern of contamination when writing a paper-based assessment. Therefore, it became increasingly important that teaching, learning, and assessment migrate from print and face-to-face (F2F) formats to digital and online platforms. Although there are existing remote and online initiatives proposed by institutions, students are still experiencing challenges in terms of relevant digital course content (eBooks), reliable online assessment, too much lecturer and student workload, lack of interactive nature of online material, etc. This paper explores the challenges and opportunities of an adaptive online learning platform used by marine engineering students at a university of technology during the national lockdown. The theoretical framework of this study is underpinned by Laurillard's conversational framework investigating the efficacy of the adaptive learning platform. Data were collected from students' performance in proficiency tests on the adaptive learning platform as well as a survey questionnaire, using both qualitative and quantitative methods of data collection and analysis. Results yielded several instructional relationships that showed students experienced deep and meaningful learning when using the platform. They also expressed positive views about adaptive online learning technology. The results provide encouraging support for incorporating technology-backed learning environments into the science classroom and suggest that the opportunities outweigh the challenges.

Hope K. Gerde Gary E. Bingham

STEM Labs: The Future of Professional Development for Early STEM

Early childhood science experiences promote the development of foundational skills needed for later STEM education (Greenfield et al., 2017). Unfortunately, STEM opportunities in many preschool classrooms serving children from under-resourced backgrounds are rare and of poor quality (Nayfeld et al., 2011; Pelliti et al., 2014). A host of factors are responsible, including limited materials/tools, time and space to work on STEM, and teachers' feeling underprepared to teach STEM to young children (Authors et al., 2018; Greenfield et al., 2009). This study examined the implementation of the STEM Lab Intervention in early learning programs (N = 51 classrooms). The STEM Lab intervention was designed by the programs to alleviate multiple barriers facing early educators. As such the STEM Lab intervention includes designated space and materials for STEM exploration, dedicated time in labs, supplementary STEM lessons aligned to the general curriculum, and teacher professional learning around STEM implementation. The findings of this study provide initial evidence of promise for the use of the

innovative STEM Lab Intervention as one way to provide high quality STEM opportunities for young children, particularly those from under-resourced communities. The instructional quality teachers provided in the STEM Lab was higher than what they provided in their regular classrooms.

Ihsan Ghazal Hayat Alhokayem

High School Students' Reasoning about the Immune System in Beirut, Lebanon

Research suggests that students hold misconceptions about microbes, antibiotics, and the immune system, but little is known about how they reason concerning the mechanisms of how the immune system functions. This study investigated how grade 12 students reason about the immune system in Beirut, Lebanon. The participants were 16 grade 12 students who were taught a unit about the immune system for 1 month. We analyzed pre/post assessment and post semi-structured interviews to determine the levels of reasoning. The results revealed 5 levels of reasoning: level 1 was demonstrating informal reasoning, level 2 was recognizing the general function of the immune system without any reference to a mechanism, level 3 was recognizing simple mechanisms without identifying the relationship between the specific and non-specific immune system, level 4 was recognizing the complex mechanism of different parts of the immune system without relating the microscopic elements to the macroscopic response, and level 5 was recognizing the complex mechanisms between the different parts of the immune system for the microscopic elements to the macroscopic response, and level 5 was recognizing the complex mechanisms between the different parts of the immune system including the relationship of the microscopic elements to the macroscopic response. We discuss the implications of those results for curriculum and instruction.

Ava Marie Gibler Alexis Van Howe

Bringing the Outside In and Inside Out: Connecting Socioemotional Learning with Science

Despite the opportunities in environmental education, K-8 teachers remain overwhelmed by the required tasks, performance expectations and content areas, especially as they return to in-person instruction. Considering the multifaceted challenges, we investigated how environmental science literacy could empower elementary teachers and students. We examined a week-long professional development providing standards-based tools and strategies surrounding environmental and socioemotional learning. We applied a design-based research approach to analyze PD artifacts and 42 teachers' surveys to understand the effect of design decisions addressing teachers' needs through integrated science and SEL. We found teachers were highly concerned with "learning loss" and students' socioemotional readjustment. Exploring the tension between academic content and SEL led PD facilitators to focus on integrating SEL and science. While teachers came in with rich ideas around the SEL dimensions of self-management, self-awareness, and relationship skills, they focused on individual development and lacked confidence integrating SEL with science. Throughout the PD, teachers deepened their views of SEL in relation to science in four ways: experience joy as a learner, foreground discovery, simplify standards, and build community. For example, teachers shifted their SEL focus away from self-management and toward social awareness, building a community where students connected with science and each other.

Minyoung Gil Matthew Johnson

The types of feedback used by teacher educators in engineering design workshops and their effectiveness

Recently, interest in equal engineering education has been increasing, and teaching engineering content and practice in school has also attracted attention. However, this has come as a significant challenge for teachers who do not have experience in engineering teaching or teachers in under-resourced schools or rural schools. Effective teacher education requires understanding learners' positions through practice-based activities and strategic feedback from teachers' educators. In this study, the level of feedback was used as a framework to examine the types and effects of feedback used by teacher educators in engineering design workshops. The analysis shows that teacher educators used task and process levels of feedback evenly, a small number of self-regulation feedback, and no self-level feedback. Teacher educators with higher engineering teaching experience used various strategies at the process level of feedback. Also, all teachers responded that teacher educators facilitated their learning. Thus, this study suggests that it is important to use both task and process levels of feedback in teacher educators on obtaining practice-based experience. Finally, teacher educators are recommended to allow teachers to contemplate how to implement engineering education in classrooms.

Anna Gillespie-Schneider Lorraine Franco

Categorizing Classroom-based Argumentation in Elementary STEM Lessons: Applying Walton's Dialogue Theory

Argumentation is a science practice that spans STEM disciplines and is an explicit goal for K12 students in reform documents. The purpose of this study was to investigate a method for analyzing the kinds of arguments that elementary teachers and students can engage in when learning STEM concepts, in particular, when learning science, mathematics, and how to code robots. Our research question was: What types of arguments are evident in elementary STEM lessons? The data included video recordings of STEM lessons in two elementary level teachers' classrooms. Our primary focus was to determine the applicability of Walton's (2010) typology of argument dialogues to episodes of argumentation in elementary STEM context. Our research suggests that in addition to having opportunities to argue in K12 STEM education, students also need opportunities to engage with arguments that have a diverse range of goals (e.g., to prove a hypothesis vs. to persuade) and understand how these goals impact their argumentative discourse. While our work takes place in the United States with teachers of children in grades 3-5 (ages 8-10 years), we believe our approach is applicable to elementary classrooms around the world.

Tamar Ginzburg Miri I. Barak

Technology-enhanced Inquiry-based Learning: Facilitating Motivation to Learn Science Among Elementary School Students

Inquiry-based learning has been an important component of science education worldwide starting at an early age. However, one of the challenges that teachers are facing in effectively implementing this instructional strategy is motivating their students to learn science. As the unexpected spread of the COVID-19 further illustrated, there is an urgency to overcome the barriers to online education and shift IBL to the digital realm. To address this need, the current study's goal was to examine the motivation of elementary school students to learn science and to identify design components of a technology-enhanced IBL that may foster science learning and motivation. The study applied a sequential exploratory mixed-methods approach and included a motivation questionnaire (N=109) and semi-structured interviews (N=7). The findings indicated overall medium levels of motivation among the participating sixth-grade students, with greater motivation for cross-cultural interactions. Differences between the Israeli and American students were also observed. Findings also pointed to the importance of seamlessly embedding technology to support the cross-cultural learning of scientific practices along the inquiry cycle. Effectively linking IBL with technological tools, while building on the willingness of students and teachers to engage in cross-cultural learning communities, may promote global scientific literacy.

Aline Gjelaj Jessica White

Creating Unity and Inclusion Through Developing the Research Team Teacher Role

In this presentation, a team of practicing teachers and teacher educators will describe their learning from the first year of a five-year, cross-institutional NSF-funded project focused on how teacher education programs prepare their graduates for culturally responsive science teaching. The teachers on this project are full members of the research team and are developing a role named "Research Team Teacher" (RTT). The question addressed in this presentation is: What are we, as practicing teachers, learning through our professional learning and research team experiences about the role of Research Team Teachers? Two RTTs, graduates from two different teacher education programs, led the creation of findings and will lead the presentation, elaborating on the themes they developed to describe their experiences on the project in its first year: Understanding culturally responsive education and qualitative research skills as a part of the research project, Providing professional development, and Establishing community and unity within the education profession, demonstrated in the RTTs' increased network of collaborative educators – including practicing teachers across the country as well as teacher educators - as they continue to grow and reflect on their own practice.

María González-Howard Sage Andersen

Language for scientific sensemaking: Examining a teacher's understandings and instruction for supporting their multilingual students

Reform-oriented science instruction centers sensemaking responsibility on students; students do not learn science from their teacher, but instead figure out ideas with their classmates. The various processes that occur as students engage in scientific sensemaking require that they use language -

across both linguistic and non-linguistic modes of expression - in complex ways. As such, teachers need to have nuanced understandings of the relationship between language and scientific sensemaking to ensure that all their students authentically engage with, make sense of, and communicate ideas around natural phenomena. This is particularly important when considering the experiences of multilingual students, a student population that has been historically excluded from rigorous science learning. This exploratory study investigates a teacher's understanding of language and its role in scientific sensemaking, and the relationship between this understanding and their instruction for supporting multilingual students during the enactment of a reform-oriented science curriculum. Findings revealed that the focal teacher held a range of ideas around what "counts" as language in the context of science education, and the ways that language is used to construct knowledge. These ideas around language manifested in their instructional practices, sometimes supporting, and other times hindering, his multilingual students' scientific sensemaking.

Alexis Gonzalez-Donoso Samia Khan

A Cross-Case Analysis of In-Service Science Teacher's Assessment Literacy in Model-Based Teaching

Despite a growing body of research on teaching with models. there is relatively less research focused on in-service science teachers' assessment strategies to assess these models. In this study, an interpretavist approach to research was followed to investigate In-service science teachers (ISTs)' assessment literacy in MBT. Five secondary ISTs participated in an online professional development course on MBT. Their pedagogy was observed before and after the course. The results showed that ISTs' knowledge about models and modeling was enriched after the OPDC but ISTs still struggled to engage and assess students in modeling. Moreover, ISTs lacked a repertoire to assess the generation, evaluation, and modification of models. This study aims to address the following research questions: RQ1: How does science teachers' assessment literacy in MBT (ALMBT) is enriched after attending and online professional development course; and RQ2: How does in-service science teachers' ALMBT influences their pedagogy.

Karen C. Goodnough Saiqa Azam

Examining Science Teacher Educators' Perspectives of Inclusion

In the study described in this proposal, we examined the views of science teacher educators (STEs) in relation to inclusion. Because limited research exists in this area, we designed this study to describe STEs' conceptions of inclusion; document the theories, principles and concepts that guide STEs' work related to inclusion; report on STEs' views of their role in preparing teacher candidates for inclusivity; and investigate how contextual factors enhance or hinder STEs' adoption of inclusive pedagogy. A sequential, mixed methods explanatory design (Creswell, 2005), consisting of a quantitative phase followed by a qualitative phase, was adopted. In phase 1, the focus of this proposal, we collected data from STEs through a national online survey consisting of both closed and open items. This research is unique and important because it provides a valuable knowledge source for new and current STEs. It has the potential to have significant scholarly and societal impacts, especially in Canada. It is informing the knowledge base for science teacher educator inclusive pedagogy and the pedagogy of science teacher

education, thus helping to prepare teachers who have the knowledge, skills, and dispositions to be effective inclusive educators.

Angela N. Google Jeremiah Henning

Development of Multidimensional Framework for Exploring Undergraduates' Conceptions of Studying Science: Student and Faculty Perspectives

At the undergraduate level, the act of studying is consistently expected by instructors and heavily explored by education researchers, yet often ill-defined as to what activities constitute as studying. Inconsistencies with defining the act of studying leads to misalignment between faculty expectations and student study behaviors. Few studies consider the multiple social and academic factors that make up and influence the act of studying in a way that is useful for faculty and students. This study proposes a multidimensional way to conceptualize studying by comparing diverse conceptualizations of studying from both undergraduate science majors and science faculty. Findings revealed some overlap between how students and faculty conceptualize studying. Participants' definitions, goals and motivations of studying resulted into three themes: process, products, and context. These findings have implications for promoting positive student learning experiences, improving equity within science classrooms, and increasing interpretive validity of participant research responses. Lastly, a nuanced understanding of studying from the students' perspective is needed to design more comprehensive academic interventions at both the classroom and institutional level.

Angela N. Google Jeremiah Henning

Bridge/or Barrier? Institutional Agents Shape Sense of Belonging for First-Generation STEM Students Holding Intersecting Identities

First-generation college students (FGCSs), make up over one-third of the undergraduate student population nation-wide, and much larger portions at many regional public 4-year institutions. Studies indicate that FGCSs are less likely to enter college, and once enrolled are less likely to persist and earn a degree relative to continuing-generation students. Additionally, FGCSs experience unique and persistent challenges in their pursuit of undergraduate STEM degrees. FGCSs experience greater social alienation and marginalization due to a mismatch of cultural values and report lower sense of belonging, which is often compounded by the fact that many FGCSs hold multiple marginalized identities. Sense of belonging impacts students' academic achievement, persistence, and overall student success, especially for historically-excluded minority groups. Few studies have examined factors that contribute to institutional and disciplinary belongingness for students with intersecting marginalized identities, as well as the key institutional agents that potentially facilitate or hinder their academic progress. In this light, our work examined the unique experiences of FGCSs holding multiple social identities that are historically underrepresented in STEM (i.e., race/ethnicity, gender, religious, lower social class) and how their experiences shaped their sense of institutional and disciplinary belongingness, STEM identity, and perceptions of institutional inclusivity.

Rachael M. Gordon

Learning Antiracist and Socially Just STEM Teaching Within an Embedded, Place-Based Model of Teacher Education

This qualitative study explores pre-service and novice STEM teachers' opportunities to learn antiracist and socially just (ARSJ) teaching within an embedded and place-based model of teacher education. Supports for pre-service and novice teachers included: working alongside a mentor teacher, observation of self-selected class hours, and weekly individual coaching sessions and support meetings. The author collected data and served as support coach to novice STEM teachers throughout the academic year. Supports were anchored around a definition of ARSJ STEM teaching, consisting of four core teaching practices that position students as cultural experts, connects connect to social justice, highlights meaningful BIPOC figures in STEM, and provides opportunities to critique the status quo. Interviews were analyzed to explore the following questions: What and how do interns and novice STEM teachers learn about ARSJ teaching within an embedded and place-based model of teacher education? What affordances and constraints does such a model present in supporting interns and novice STEM teachers' opportunities to learn ARSJ teaching practice? Although learning communities provided structure and support for pre-service and novice STEM teachers, virtual learning and disciplinary connections were challenges in implementing ARSJ teaching practice. The study has implications for science teacher education design.

Dilara Goren Ebru Kaya

Middle School Students' Understanding of Nature of Science and Their Metacognitive Awareness

The study investigates the relationship between middle school students' understanding of Nature of Science (NOS) and their metacognitive awareness with theoretical framework of the "Reconceptualized Family Resemblance Approach to Nature of Science (RFN)". Totally 701 (180 5th, 167 6th, 170 7th and 184 8th grade) middle school students participated to the study and 12 students among them (3 from each grade level) were interviewed. The data sources are "RFN Student Questionnaire", "Metacognitive Awareness Inventory for Children" and interview questions. The data was analysed through Pearson product moment and thematic analysis. As a result, Pearson r correlation shows that there is a statistically significant positive relationship between middle school students' answers for the RFN and metacognitive awareness. Moreover, the interview results show that students' answers for the RFN and metacognitive awareness related questions were matching and compatible. The students who were metacognitive awareness had a low RFN understanding. When considering the relationship between students' RFN understanding and their metacognitive awareness had a low RFN understanding. When considering the relationship between students' RFN understanding and their metacognitive awareness had a low RFN understanding. When considering the relationship between students' RFN understanding and their metacognitive awareness had a low RFN understanding. When considering the relationship between students' RFN understanding and their metacognitive awareness, this study contributes the further studies for examining the use of metacognitive strategies in RFN teaching.

Amelia Wenk Gotwals Amber S. Bismack

Supporting Early Elementary Science and Literacy Teaching: The Synergy of Pedagogical Tools

Elementary science education has the potential to build on students' natural curiosities about their world, promote scientific literacy, and foster positive science identity development. When science is taught with reform-oriented methods such as phenomenon-based inquiry, it can promote equitable science learning opportunities for students as they see themselves as knowers and doers of science. However, these methods are not intuitive for many teachers, and few professional development opportunities are available for elementary teachers of science. This related paper set, including three studies from across the U.S. and one from Europe, considers the affordances of curricular infrastructure-construed broadly to include curriculum, curriculum materials, and standards--as boundary objects to support the professional learning of elementary teachers towards enacting more reform-oriented science teaching methods. In each paper, teachers engaged with these boundary objects in collaboration with partners to transform aspects of their science teaching and professional identities. With limited opportunities for professional learning for elementary teachers of science, it is imperative that the field continues to grow in our understanding of how to make a difference in their science teaching practices, and the papers in this set each bring a different and critical lens to this challenge.

Ezra Gouvea Brian E Gravel

Developing Disciplinary Relationships in Computational Physics

Learning environments designed to engage students in authentic forms of scientific practice must reflect the heterogeneous nature of disciplinary learning. Central to professional science is the active coordination of multiple threads in the practices of doing science. These organizing acts weave together the technical, social, political, and material elements of inquiry in ways that achieve shared, cultural goals. Within these sociomaterial entanglements, agency is distributed among learners, materials, and tools in ways that expand and deepen our collective sense of what it means to learn science. This session specifically examines and codifies themes relating the material natures of learning in college science courses, through shared focus on agency, computation and simulation, and disciplinary inquiry. Drawing from recent moves away from the "cookbook" and prescribed laboratory experiences, this related paper set presents four unique studies that center and explore issues of materiality in college science learning. They include (1) exploring how introductory physics instructors design for sociomaterial entanglements, (2) attention to students' trajectories of practice navigating uncertainty, (3) students' creative hacking of laboratory materials to develop models, and (4) disciplinary practices presented as a series of conversations that students have with themselves, with others, and with materials and representations.

Donna Governor April Nelms

Science and Engineering Practices and Cognitive Demand Present in Preservice Teachers' Planning and Instruction

The Frameworks for K-12 Science Education signaled a shift in the teaching of science as content and process to engaging students in science practices. The Science and Engineering Practices (SEPs) require a

level of cognitive rigor not delineated in prior national standards. Through the Practice Based Teacher Education (PBTE) framework, this paper analyzes the presence of SEPs and levels of cognitive demand using Bloom's Revised Taxonomy in the planning and instruction of preservice teachers. Researchers utilized generic qualitative inquiry methodology to examine teaching artifacts. The results indicated that preservice teachers (PSTs) plan and teach using mostly the lower three levels of Bloom's Revised Taxonomy, engaged students least often in Engaging in Argument from Evidence, and engaged students in SEPs beyond those designed in their lesson plans. When using lower cognitive levels, PSTs included Investigations and Constructing Explanations most often. PSTs who reached higher cognitive levels included data analysis in their instruction and those who reached the highest cognitive levels used at least three different SEPs. Through the lens of the PBTE framework, this study emphasized the need to conduct further research on how best to prepare PSTs for the demands of engaging students in science practices.

Vanessa Grady Natalie S. King

STEM Education through Abolitionist Teaching: A Research-Practice Partnership to Support Virtual Microteaching Experiences

In this paper, we share an approach to address systemic racism by highlighting a research-practice partnership [RPP] effort between a university and STEM program (STARS*) to understand the extent to which centering abolitionist teaching and emancipatory practices in a science methods course supported teacher candidates' virtual microteaching experiences. This study's conceptual framework put research-practice partnership (Penuel & Gallagher, 2017) in conversation with abolitionist teaching and learning. Findings revealed that the teacher candidates embraced the concept of abolitionist teaching to inform their microteaching experiences by leveraging social justice standards and emancipatory pedagogies. The participants developed science lessons that honored students' cultural capital through critical readings, discussions, and reflections. Furthermore, the RPP between STARS* and the partnering university provided supports to contextualize and humanize science learning for Black and Brown children in online learning spaces. In order to expose and dismantle racism in science education, we must reimagine our science teacher preparation programs and courses. To emancipate STEM education is to engage in the struggle toward humanity and collective healing. Abolitionist teaching within the context of science education does not require another reform effort.

Nicole Graulich Marc Rodemer

Applying visual highlighting techniques to support students' understanding in Organic chemistry

Research in science education demonstrates that a key challenges for learners in the science disciplines is certainly connecting domain-specific representations to the underlying concepts. Purposefully designed highlighting techniques in multimedia instructions, as used in other domains, might be a promising way to support students to make applicable connections between representations and conceptual knowledge. To examine the influence of different highlighting techniques on student

learning, 171 chemistry undergraduate students in an organic chemistry course were provided with tutorial videos, showing typical substitutions reactions, either with static, dynamic or without (control) highlighting. The results show that students' learning gains increased for all groups respectively. However, students viewing tutorial videos with dynamic highlighting gave more sophisticated answers in direct retention tasks, compared to the other treatment group and control group. Furthermore, the results indicate that low prior knowledge of students is compensated by both static and dynamic highlighting techniques. Besides student learning outcomes, students' evaluation of the different tutorial videos shows significant benefits of the highlighted instructions in terms of perceiving higher comprehensibility. The results support the use of appropriate highlighting techniques in instructional formats to support students in linking conceptual knowledge and to representations.

Leroy Groβmann Merryn Dawborn-Gundlach

Pre-Service Biology Teachers' PCK about Scientific Reasoning

For successful teaching, science teachers need professional competencies encompassing professional knowledge including pedagogical content knowledge (PCK) and content knowledge (CK) as well as motivational orientations (e.g., self-efficacy, SE). As fostering scientific reasoning competencies among students is a crucial aim in science education, science teachers need specific PCK, CK and SE for teaching scientific reasoning (PCK-SR, CK-SR, SE-SR). The purpose of the current study is (1) to provide a new 12-items multiple-choice instrument to measure pre-service biology teachers' (N=67) PCK-SR, (2) to investigate its psychometric properties and (3) to investigate the relationships between PCK-SR, CK-SR and SE-SR. Data were analyzed within the framework of item response theory. Findings suggest appropriate psychometric properties for most items of the new instrument (e.g., MNSQ values). We found a significant positive correlation between PCK-SR and CK-SR (r=.41, p=.001) but not between PCK-SR and SE-SR (r=.06, p=.616). A latent class analysis suggested two subgroups of the present sample. For one subgroup (n=25), there is a significant negative correlation between PCK-SR and SE-SR (r=.41, p=.044). Findings will be discussed with regard to the specific teacher education program of the sample and related to PCK research in science education.

Michele L. Guannel Olivia Diana

Incorporation of a Utility-Value Intervention into a Place-Based, Culturally Sustaining General Education Science Course

A freshman-level science course, at a Historically Black College/University (HBCU) in southeastern North America, focuses on local natural hazards and ecosystems. To bolster course engagement further, we incorporated a utility-value intervention developed at a Primarily White Institution, in which students were prompted to describe the personal relevance of science content. During Fall 2020 and Spring 2021, students were assigned a utility-value essay or an objective essay on the same topic, for a total of three assignments per semester. Final grades did not differ significantly between the two groups, for either semester. However, as a potential marker of increased course engagement, we found significantly higher word counts in utility-value essays, compared to objective essays. Furthermore, a trend in higher utility associated with Fall 2020 assignments may indicate higher appreciation of natural phenomena during hurricane season. One assignment was examined for common themes; students completing both utility-value and objective essays described the relevance of climate change in terms of hurricanes and other impacts on their lives. We argue that HBCU and other underrepresented minority students already recognize the importance of science through their lived experiences, including disproportionate impacts of climate change, disasters, and environmental injustice upon persons of color.

Sarah K. Guffey Andrea C. Burrows

Impact of STEM Professionals Engaging with Students in Title One Schools

The STEM fields have faced challenges in producing enough graduates to meet workforce needs in these areas (van den Hurk & van Langen, 2019). Additionally, recruiting and retaining marginalized students in STEM fields has proven to be a challenge (Green et al., 2020). This collaborative action research study raised awareness of STEM careers to underrepresented students in a southeastern title one high school by inviting STEM professionals to facilitate an open dialogue about their pathway into STEM. The STEM career interest survey (Kier et al., 2013) was administered to gauge students' interest in STEM. Results showed that after engaging with STEM professionals, students had a greater interest in pursuing a STEM career.

Kristin L. Gunckel Daniel L. Moreno

Examining the crosscutting concept of patterns: An initial construct map in the context of ecosystems

We present work to assess student competencies for the crosscutting concept of patterns. Our research is based on the BEAR Assessment System, grounded in four building blocks (e.g., construct map, item design, outcome space, and measurement model) which guide assessment development. Our first challenge was to develop a suitable construct map. For this, we focused on students' increasingly sophisticated thinking about patterns in ecosystems. We then developed assessment items that included representations of these patterns using both graphs and maps. The items were administered to 176 middle school students and scored using the initial levels in the construct map. Findings indicate that items that prompt students to describe specific patterns were qualitatively easier for students than items that asked students to describe patterns. Familiarity with representations and relevant disciplinary knowledge may also influence student proficiency in finding patterns. These findings will inform the eventual development of a learning progression for the patterns crosscutting concept. Given the field's limited understanding of the crosscutting concepts, let alone how to assess them, we envisage this work will be of considerable interest to NARST members.

Amanda M. Gunning Meghan E. Marrero

Exploring How Engineering Instruction Supports Culturally Relevant Teaching Practices

This study examines how 23 in-service pK-12 teachers taking a Teaching Engineering course designed and conducted engineering lessons and units that changed their teaching practice through lenses of culturally relevant pedagogy (CRP) and social justice. Findings suggest that engineering education lends itself to supporting culturally relevant pedagogy, especially promoting social, community, and environmental critique through an engineering lens. During four semesters of data collection, researchers collected qualitative data and used the TESS scale to study teachers' development of selfefficacy for teaching engineering. What emerged from the data was the social justice and CRP approaches employed in the course were supported by teaching engineering methods for the pK-12 classroom. The findings in this proposal are preliminary, as data collection is ongoing. We will have more to share by the time of the conference meeting.

Shuchen Guo Enshan Liu

Enhancing Gifted Students' Attitudes toward STEM: An Insight from a Research Apprenticeship Program

Research apprenticeship is a very typical and important way to enhance students' attitudes toward science/engineering. However, most studies only focus on changes in student outcomes using retrospective studies. Few studies adopted a longitudinal manner, with attention paid to changes and influential factors of attitudes during the program. Meanwhile in Asia context, few studies have been conducted about the contribution for research apprenticeship for students, which makes the effects of such program remains uncertain. Thus, this study aimed at a research apprenticeship program for gifted students in China. Using mainly qualitative method, the purpose was to evaluate the changes and the influential factors of the participants' attitudes towards STEM during the program. Qualitative data showed that attitudes of most participants increased in some dimensions. Students' interest was found to be influenced by knowing more, problem solving, authentic inquiry experience and meaningfulness. Self-efficacy was found to be influenced by mastery experience, vicarious experience and social persuasion. Perceived value was influenced by students' understanding of the communal goal of the research topic. Intention was influenced by interest, being critical and students' self-efficacy.

Kristie S. Gutierrez Jennifer Kidd

"It truly benefited me!": Surprising Learning Benefits for Collaborating Education and Engineering Undergraduates During COVID

Using Bandura's Social Cognitive Theory framework, this study examines how the COVID-19 context and shift to online instruction influenced preservice teachers' and undergraduate engineering students' learning experiences as they worked in teams to adapt and deliver hands-on engineering lessons to elementary students in a virtual format. Written reflections and focus group interviews were analyzed to explore the influence of COVID-19 on university students' personal learning and affect. As students made significant changes to the ways in which they were attempting to communicate engineering content to 4th and 5th grade audiences, they learned different skills than initially expected, experienced different challenges than anticipated, and had a myriad of affective responses to those experiences. Student data revealed three interdependent themes related to the change in lesson delivery mode: (1) paying attention to online pedagogy, (2) learning from lesson modifications, and (3) affective outcomes from lesson modifications. The students' experiences adapting to the changes in environmental factors due to COVID-19 provide insight for all educators, including those involved in teacher and engineer preparation programs, as they consider the best ways to support student learning, both face-to-face and online, and in stressful and unpredictable contexts such as those experienced during the pandemic.

Candice R. Guy-Gaytán Suzanne Lewis

Investigating Students' Reasoning on a Practices-based Exam

This related paper set presents the results of our work developing and implementing a threedimensional district biology assessment within the context of a research-practice partnership. We include our practice partners as lead co-authors to demonstrate our commitment to valuing practice perspectives in science education. Paper 1 describes the district science curriculum coordinator's decision-making about the development of the assessment, including successes and challenges of the process. Paper 2 describes how the district implemented the assessment and used the data from administration of the assessment to all high school biology students in the district. Paper 3 investigates teachers' professional learning experiences as an item writer on the assessment development team. Finally, Paper 4 investigates students' reasoning on the assessment using a think-aloud protocol. Altogether, these four papers highlight different aspects of the development and implementation process of a district science assessment from both practice and research perspectives and contributes to our understanding of the challenges of enacting educational reforms in complex educational systems.

Heesoo Ha Ying-Chih Chen

Instructional Strategies to Manage Scientific Uncertainties for Productive Sensemaking: Exploring Korean and American Classrooms

This study aims to explore instructional strategies to manage students' scientific uncertainties in sensemaking activities in the science classroom. Sense-making activities in four science teachers' classrooms were analyzed for this study, two from Korea and two from the USA. The analyzed data include videorecording of classroom discourses and transcripts of the recordings. Scientific uncertainties were coded, and six themes about features of teachers' instructional strategies that supported students' productive management of the uncertainties were identified through analysis. The themes are: (a) problematize problems regarding not only what students know (content uncertainty) but also how to explain (epistemic uncertainty), (b) use scientific uncertainty to encourage students to re-collect evidence, (c) use scientific uncertainty to clarify what students learned and construct more sophisticated explanations, (d) encourage students to utilize scientific practices to resolve scientific uncertainties, (e) use scientific uncertainties to reflect on students' reasoning, and (f) use scientific uncertainties to plan further sense-making processes. We believe that this study could contribute to developing teaching for students' engagement in sense-making in the science classroom.

Kara Haas Tali Tal

The role of professional learning in the development of questioning

In the U.S. recent widespread adoption of the Next Generation Science Standards (NGSS) has required deeper knowledge and different instructional practices from all teachers. The ability to take up NGSS-aligned practices is particularly challenging in under-resourced urban school contexts. Our work has centered on developing sustainable partnerships between teachers and informal science educators

(ISErs) to support deeper understanding of how to provide outdoor experiences which are NGSS-aligned and teaching that is specific to their place and the cultural and social needs of their students, making use of several frameworks, including place-based, design-based implementation research, culturally responsive teaching and heads-on, hands-on, hearts-on (3H). In this related paper set, we consider the work ISErs do with other educators, students, and the general public, and how these contribute to their identity (Paper1); evaluate theoretical frameworks as interpretive lenses on such partnerships (Paper2); address how we made use of a virtual environment to establish professional community and "set the stage" for summer and school-year learning (Paper3); investigate the program's impact on teachers questioning and subsequent planning intentions (Paper4); address how specific contextual factors shaped the ways the program was taken up and our leveraging of these factors to support participant learning (Paper5).

Bobby Habig Preeti Gupta

A meta-synthesis on the impact of informal STEM programs on STEM major and STEM career awareness, interest, and engagement

A critical challenge facing educators is to understand what motivates youth, especially those from historically underrepresented groups, to persist in a STEM trajectory. The goal of this study was to perform a meta-synthesis of research on youth participants of informal STEM programs. The proposed research addressed two major questions: (1) How and to what extent do informal, out-of-school time STEM learning experiences impact participants' awareness, interest and engagement in STEM majors and careers? (2) What are the program design principles, technology-based innovations, theoretical underpinnings, and best practices of rigorously designed informal, out-of-school time STEM programs that exhibit exemplary evidence of impact that can be adopted by STEM practitioners to maximize impact and broaden participation of underrepresented groups? We used two validated rubrics to identify studies that exhibit exemplary research design and evidence of impact. In a comprehensive review of over 600 papers, we found that long-term participation in informal science programs was positively associated with broadening participation in STEM trajectories. Our findings suggest that informal science programs play a critical role in fostering equity and for motivating youth to persist in STEM trajectories.

Claudia Hagan Sierra L. Morandi

"I wanted to break the pencil": The Teacher's Role in Reframing Moments of Epistemic Vexation

Science Education has transitioned to science proficiency-- students are to gain the ability to engage in sense-making about the natural world (National Research Council [NRC, 2012])--learning to "figure things out" (Passmore, 2014). One emerging area of focus is the emotional work students participate in during science sense-making. There is growing recognition that these emotions are not just unnecessary by-products of scientific work, but rather they are part-and-parcel of doing science, as these emotions are part of what "instigates and stabilizes disciplinary engagement" in scientific pursuits (Jaber &

Hammer, 2016b, p. 189). The research question that guided this study is: What is the teacher's role in reframing moments of epistemic vexation, so students experience productive meta-affect in the science classroom? After reviewing video footage and student and teacher interviews, three themes emerged: (1) Without reframing from the teacher during moments of epistemic vexation, students disengage from sense-making, (2) Productive meta-affect is more likely to occur when students understand why the teacher allows for failure to connect ideas or understand scientific concepts, and (3) When the teacher does not reframe moments of epistemic vexation, students build solidarity and reach out to each other for emotional support in developing productive meta-affect.

Kevin Hall Stina Krist

Perspectives on generalizability in problem-solving from undergraduate physics students: Influences of a mastery homework approach

Despite a growing awareness of the importance of epistemological views in learning physics, many undergraduate physics courses, including those incorporating an explicit focus on developing expert-like beliefs, can have a negative effect on students' surveyed epistemologies. Why is this? One hypothesis is that students' perceptions of their experience in these activities may contradict the instructional intent. This study explores this hypothesis by examining how students perceive and understand their experiences with a mastery homework system in an introductory physics course. Drawing on interviews with 6 students asking them to reflect on their experiences solving homework problems, we examine how differences in perceived experiences of learning physics potentially impact students' epistemological views about the generalizability or fragmentation of nature of physics knowledge. Preliminary findings suggest (a) some students viewed general concepts as important and useful, but experiences varied as to whether the homework structure supported or impeded conceptual learning; and (b) most students described multiple, significant ways that surface features is indicative of naivete in problem-solving and suggest the importance of understanding the role of course structures such as homework problems in students' epistemological development.

SARAH HALWANY Jennifer Adams

Multiplying Perspectives on Racial Equity in STEM Education: Insights from Canada, Netherlands, and the USA.

STEM (science, technology, engineering, mathematics, and computer science) majors and careers maintain a long-standing underrepresentation of Black, Indigenous, and other racialized groups (hereafter BIPOC) (Evangelista et al., 2020). As such, scholars aim to have a deeper understanding of the institutional, political, and social structures that influence the experiences of racialized people in STEM and STEM education to identify points of transformation towards inclusion and flourishing. Framed around the question "how can we foster national/international research, collaborations and dialogues to address racial equity in STEM", this session seeks to multiply perspectives that address racial/social identity equity in STEM education, bringing scholars from Canada, Netherlands and the USA to discuss
theoretical, empirical, and practical approaches to address racial equity that also consider the larger contexts that structure science teaching and learning. Presenters will then facilitate small group discussions with the participants around themes and topics presented and discuss larger implications for advancing racial equity in science/STEM teaching and learning.

Sarah El Halwany Mohammad Nurul-Hassan

Teaching with Emotions: Supporting Critical Views on Nature of Science

Humanity is facing myriad 'wicked' problems — including those linked to climate, surveillance systems, manufactured foods, habitats and related species diversities — associated with capitalism-influenced fields of science and technology. Assuming capitalist manipulation of public knowledge and subjectivities and learners' diverse abilities, cultural and social capital, etc., the five papers in this Related Paper set provide theoretical and empirically-based evaluations of a constructivism-informed pegagogical schema (ReActions) that prioritizes direct teacher instruction of often difficult-to-discover conceptions in relationships among science and technology and societies and environments and education encouraging and enabling students to independently implement sociopolitical actions to overcome harms like those above of their concern. The five papers appear to support Unity and Inclusion for Global Scientific Literacy through qualitative action research to apply and evaluate the ReActions schema in multiple educational contexts (primary, secondary & tertiary), drawing from Science & Technology Studies [STS]) and the arts to understand possible alignments among numerous 'actants' within a growing dispositif (i.e., purposeful machine-like actor-networks) that may promote ecojustice outcomes, like: communitycentred (vs. individualistic) goals; ecocentric (vs. anthropocentric) worldviews; tempered (vs. continuous) change; and, intrinsic (vs. exchange) values. STS conceptions apparently aiding this work include: sociotechnical imaginaries; dispositifs; phenomena-semiotic relationships; (de-)punctualization; and, governmentality.

Rebekah Hammack Tina Vo

A Comparative Case Study Investigating Indigenous/Rural Elementary Students' Conceptions of Community Engineering

Engineers work on solving problems to benefit society, and it is vital that the engineering workforce of the future is representative of society as a whole (NAE, 2013). To meet this demand, educators will need to recruit and prepare diverse students for entry into engineering careers. This includes students from underrepresented groups (i.e., Native Americans) and locations (i.e., rural and reservation communities) who have local funds of knowledge which can be used to target specific complex problems. Supporting students' thinking of engineering early is essential to build up the workforce needed to address these complex issues. Early intervention allowing them time and space to build their ideas about engineering. The current work is part of a multi-year study designed to increase awareness and preparedness of rural and indigenous youth to pursue engineering and engineering-related careers. To help identify local funds of knowledge, the research team developed photo novella prompts that participating teachers assigned to elementary students. We found distinct differences between how students from different

spaces conceptualized engineering, including how they connected science and engineering, the role engineering played in their lives, and ideas of possession.

James B. Hancock Jack T Poling

Investigating Impacts of Professional Development on High School Physics Teachers' Collaboration and Lesson Planning

Professional development (PD) can positively impact teachers' collaboration and lesson planning, which are critical for student success. COVID-19 necessitated shifts in PD during the 2020-2021 academic year, and through this qualitative multiple case study research we sought to understand if and how shifts in PD offerings affected high school physics teachers' lesson planning and collaboration. Megan and Mark, two veteran physics teachers in substantively different contexts, had contrasting PD experiences during COVID. Findings suggest both teachers felt isolated and lamented the dearth of content-focused PD. Mark, a teacher at a mid-sized suburban high school, was provided PD on social interactions that he felt positively impacted how he talked with students. However, Mark wished he had been provided content-specific PD focused on online teaching, and he desired more time to develop collaborative relationships will school-based physics colleagues. Megan, a science teacher at a very small rural school, proactively sought content-focused PD from outside her district and, due to her isolation, continued to engage in physics-specific collaborations among colleagues from outside her school. Our findings echo prior research that suggests maintaining a focus on content is important and further elucidates differences in teachers' perceived needs and challenges with respect to PD.

Jacqueline Handley

Examining Moments of Liberatory Design Possibility in Youth-centered Engineering Design Practice

The purpose of this study was to examine how to develop meaningful engineering experiences for youth that might counter decontextualized and often exclusionary approaches. I argue that engineering design with young people could be a very youth-centered space, addressing the concerns of young people through engineering design practice. However, youth are often not invited into real-world, flexible, front-end engineering design work that deeply impacts the potential for liberatory and just design. Drawing on critical sociocultural learning theories and critical science and technology studies (STS) of design, I analyzed in what ways four youths' engagement in and discussion of a community engagement program – intentionally designed to counter decontextualized, building-centered engineering – opened opportunities for youth to think critically about design practice and enact liberatory design work. This qualitative study was informed by design-based research methods that center participants' experience as crucial data for informing design. Findings discuss how youth leveraged personal knowledges in developing data collection tools to explore a community problem of interest, opening moments of liberatory design possibility in their design trajectories.

Deborah L. Hanuscin Josie C. Melton

Variation in the Implementation of Educative Curriculum Materials for Teacher Educators in Two Course Contexts

Teacher educators vary in their disciplinary backgrounds, entry points, and preparation for teaching teachers. Given the effective use of educative curriculum materials (ECM) to support teacher learning, we developed a set of ECM to support teacher educator learning. In this study, we report on two cases from implementation of ECM designed to support teacher educators in promoting the development of preservice elementary teachers' content knowledge for teaching about matter and its interactions. Participants were two full professors with different backgrounds teaching different courses for elementary preservice teachers at a public university in the Pacific Northwest. The first has a chemistry background teaches a science content course for teachers, and the other has a science education background and teaches a science methods course. While both instructors made principled and productive features. Our findings suggest that ECM for teacher educators should be designed to provide support for using the materials for different purposes and at different times in preservice teachers' development and learning.

Susanna E. Hapgood Joan Kaderavek

Academic Impact for Preschoolers and Kindergarteners of Classroom and Family Science: A Randomized, Control-Group Study

Using a randomized, control-group design, academic outcomes for preschool and kindergarten children were compared to investigate the impact of implementing Next Generation Science Standards-aligned science and engineering (S&E) investigations with or without family engagement activities, as compared to children in "business as usual" control classrooms. Intervention groups' teachers (professional development-only [PD-only], or those who incorporated family-focused S&E engagement opportunities [PD+family]) experienced extensive PD focused on S&E content knowledge and understanding of S&E standards and high leverage pedagogical practices. Families of children in the PD+family group were provided with take-home family S&E activity packs and were invited to participate in informal community S&E events. Children's pre- and post-school year academic abilities were documented with The Early Learning Scale (preschool cohort) and The Kindergarten Early Learning Scale. Analyses of outcome data showed that, for the preschool cohort, both PD-only and PD+family intervention groups had significantly better academic outcomes than the control group. In the kindergarten cohort, children in the PD+family group performed significantly better than the control group. There was not a significant difference between the PD-only and PD+family intervention groups for either the preschool or kindergarten cohort.

Ute Harms Carola Garrecht

Socioscientific Argumentation in Science Education

Over the last decades, more and more researchers in the field of science education have been advocating for science learning that considers science-as-practice rather than solely science-as-knowledge. This shift

in perspectives has drawn particular attention to the importance of addressing scientific practices in science teaching and learning (Christodoulou & Osborne, 2014). Argumentation is such a practice, lying at the heart of science, which has also been well established within the science classroom (Erduran & Jimenez-Aleixandre, 2008). Within this symposium, we focus on the argumentation of pre-service teachers and students in particular contexts that have been labeled as socioscientific issues (Sadler, 2004). Socioscientific issues (SSI) describe complex problems found at the interface between science and society. Since these issues touch equally upon social matters and scientific content, their elaboration must be informed by scientific understanding and ethical considerations. This complexity makes SSI "ideal topics for argumentation"; (Zeidler & Sadler, 2007, p. 201). All proposals of this symposium empirically contribute to the exploration and assessment of students' socioscientific argumentation in science education. We thereby touch upon different argumentation formats (written vs. oral) and address a variety of methodological approaches.

Brian D Hartman Randy L. Bell

Teaching K12 Engineering — Educator's Views of Practices, Nature, and Knowledge

Interest in K12 Engineering has grown in recent years, with engineering literacy being a goal of the NGSS. Because research is limited on appropriate concepts to teach as part of this effort, the goal of this study is to investigate how K12 and university teachers view the domains of engineering literacy: Engineering practices, engineering knowledge, and nature of engineering (NOE). This study analyzed the results of an open-ended survey completed by 132 educators involved in teaching engineering literacy: Some from K12 classrooms (teachers of science and engineering) and some from academia (professors of science and engineering education). Participant responses were analyzed using a Grounded theory Methodology. Results indicated that participants typically defined engineering practices using terms such as activities, skills, and actions that are employed by engineers. They defined engineering knowledge as including: The engineering method, engineering disciplinary knowledge, and non-engineering knowledge. Many defined the NOE as the discovery of solutions to real-world problems, although one-third of the participants failed to respond to this item. The present investigation seeks to add to the literature on engineering literacy by elaborating the views of K12 teachers and science/engineering professors on the commonly cited engineering literacy components of nature, content, and practices.

David J Hauck Insa Melle

MOLECULAR ORBITAL THEORY IN ENTRY-LEVEL UNIVERSITY CHEMISTRY - A COMPUTER-SUPPORTED COLLABORATIVE INTERVENTION

Recent studies across the world document that over 40% of students drop out of university (Heublein, 2014; OECD, 2020). Primary reasons are the high requirements for content knowledge, which often lead to a decline in interest in the subjects taught. Central barriers in chemistry studies are subject-specific fundamentals on the one hand (Averbeck et al., 2018; Tai et al., 2005) and quantum chemical models of atoms and atomic bonding, such as molecular orbital (MO) theory (Bouayad et al., 2014; Partanen, 2018;

Taber, 2002a, 2002b), on the other hand. In this project, we developed and evaluated a two-part intervention on MO theory based on the Computer-Supported Collaborative Learning (Zurita & Nussbaum, 2004) framework: First, students engage with a digital learning environment (DLE). Then, they work together in small groups to create concept maps collaboratively. The intervention is evaluated with the help of a self-developed subject knowledge test as well as adapted questionnaires regarding the attractiveness, usability, and cognitive load of the two parts of the work. In addition to the concept maps created, the collaborative process will be analysed through audio and screen recordings.

Christa Haverly Emily Rose Seeber

Curriculum Materials Adoption Processes: Teacher Learning in an Organizational Routine

Elementary science education has the potential to build on students' natural curiosities about their world, promote scientific literacy, and foster positive science identity development. When science is taught with reform-oriented methods such as phenomenon-based inquiry, it can promote equitable science learning opportunities for students as they see themselves as knowers and doers of science. However, these methods are not intuitive for many teachers, and few professional development opportunities are available for elementary teachers of science. This related paper set, including three studies from across the U.S. and one from Europe, considers the affordances of curricular infrastructure-construed broadly to include curriculum, curriculum materials, and standards--as boundary objects to support the professional learning of elementary teachers towards enacting more reform-oriented science teaching methods. In each paper, teachers engaged with these boundary objects in collaboration with partners to transform aspects of their science teaching and professional identities. With limited opportunities for professional learning for elementary teachers of science, it is imperative that the field continues to grow in our understanding of how to make a difference in their science teaching practices, and the papers in this set each bring a different and critical lens to this challenge.

Christa Haverly Terrance Burgess

Building an Elementary Science Teacher Education Community to Advance Equity and Justice

Global society faces multiple crises, including a pandemic, climate change, racist criminalization, brutal immigration enforcement, and severe wealth inequality. These crises cannot be ignored in elementary science methods courses given the role that science plays in them, their impact on teacher candidates, and the injustices experienced by many children in schools. In response, an informally-created, U.S.-based community pivoted efforts to prepare elementary teacher candidates to be well-started beginners for teaching science towards advancing equity and justice. In this symposium, we will present findings from a systematic literature review that highlight the limited work focused on preservice elementary science teachers and topics of equity and justice. Then, a panel of early career scholars from the aforementioned community will share positionalities, institutional contexts, and work pursued and shared with one another towards equity and justice in methods courses. Attendees will deliberate topics raised by the panel in small groups. Finally, a discussant will highlight her research on preparing teacher educators to teach for equity while responding to ideas raised in the symposium. This session adds

nuance and depth to existing literature on preparing elementary science teachers for equity and justice while also expanding the community and catalyzing future research endeavors.

Cheng-Wen He Hong H. Tran

Exploring Teachers' Experience and Implementation of the Science and Engineering Practices in Different Instructional Contexts

In this presentation, we explore teachers' experience and their implementation of the science and engineering practices (SEPs) in different instructional contexts. To determine the effect of teachers' experience on the implementation of SEPs, we investigate how early career teachers and experienced teachers implement the eight SEPs in different instructional contexts during the 2020-2021 academic year. Informed by Mezirow's transformative learning theory, this paper frames teachers' experience as a critical construct, influencing how they apply their personal teaching mastery in specific instructional environments. The findings demonstrated that experienced science teachers significantly implemented more SEPs than early career teachers regardless of instructional contexts. Yet, both early career teachers might need more support in implementing SEPs in a virtual context than traditional and HyFlex (Hybrid-Flexible) contexts. The findings also indicated that the pattern of implementing the eight SEPs differed between experienced teachers and early career teachers in the HyFlex setting. This study yields new insights into what supports early career teachers and experienced teachers may need to build their personal teaching mastery to implement SEPs and how they apply it to various instructional contexts.

Peng He I-Chien Chen

Three-Dimensional Learning Progression for Supporting Students' Knowledge-in-use Proficiency in High School Project-based Learning Chemistry Curriculum

This study aims to track students' knowledge-in-use proficiency development based on the threedimensional learning progression in the context of the high school chemistry project-based learning (PBL) curriculum (i.e., three coherent units). The NSF-funded project articulated a three-dimensional learning progression of matter, interaction, and energy aligned with an NGSS-aligned PBL educative curriculum system, including curriculum, instruction, assessments, and teacher professional learning. In this study, 362 tenth-grade students with all unit assessments were selected for data analysis. Using item response models, we answer whether the items in the post-unit assessments can reliably and accurately place students' knowledge-in-use proficiency on the 3D learning progression and explore whether the 3D learning progression can be used to support students' knowledge-in-use proficiency developing to the next level. The findings of this study will contribute to teaching and learning science by providing empirical evidence on supporting students' knowledge-in-use proficiency based on an articulated 3D learning progression in an NGSS aligned curriculum system. In addition, this study will be interesting for NARST members to expand the current knowledge on investigating 3D learning progression by a longitudinal design.

Weiwei He Sihan Xiao

Examining Relevant Evidence Construction as Actor-Network in the Collective Argumentation

Researchers interested in scientific argumentation increasingly make efforts to promote students' use of evidence. To help students transition into productive scientific practice, it is important to understand their ideas of what are relevant and how they are negotiated. This study uses Actor-Network Theory to analyze the relevant actors to the community and the strategic process of constructing the argumentation. Focusing on the actors and the related translation, the findings show that three key actors – personal experiences, individual content knowledge, and students' framing – move the collective argumentation forward, and they are weighed, modified, and adopted to be meaningful for the community.

AUSTIN HEIL Julie A. Luft

"Seriously... I Want to Teach": Exploring Motivations of Science Majors Pursuing Teaching Careers

One solution to address teacher shortages in the US is to recruit more science majors into teaching careers. To better understand the motivations and factors that lead science majors to teaching careers, we conducted a qualitative study to explore the stories and experiences of four White women science major graduates currently enrolled in a teacher preparation program as recipients of a National Teaching Fellowship. Using symbolic interactionism and expectancy value theory (EVT), we conducted semi-structured interviews to uncover how participants described the transitional moments that influenced their decision to teach. Interviews were coded abductively to remain open to surprises in the data, while staying attuned to EVT. Three factors emerged from the inductive analysis that influenced participants' decision to teach: social, contextual, and extrinsic factors. Participants described motivation as contrasting expectancies in science and teaching careers. Additionally, participants most often cited intrinsic values (e.g., "I enjoy teaching) as the reason they pursued teaching. Our study provided a space for participants make sense of the factors and motivations that led them to teach, providing a deeper understanding of this decision than traditional quantitative instruments. Implications for pre-service education recruitment and equity are discussed.

Rosalie Heinen Susanne M. Heinicke

The impact of typography in learning materials of science textbook

The reading of information texts (e.g. as pages of a textbook or separate copies) in science classes constitutes a common form of knowledge acquisition. Such information pages contain explanatory texts, pictures, images and exercises. They can support autonomous learning as students can continuously turn to them and recollect information needed. Various studies have shown however, that such information pages pose general and technical language challenges to students, especially those from socially disadvantaged or migrational backgrounds. Yet, a recent study concluded that changes at the

morphosyntactic level alone produce few significant effects in terms of increasing readability. Thus, simplifying language and reducing technical terms does not demonstrate an effective measure of relief, likewise, fluency in technical language constitutes a foundational premise for scientific literacy. In the study presented based on the Cognitive Load Theory and the Theory of Multimodal Learning we explored the effect of typographical amendments in order to optimize the representation of the information without changing the text itself. Feedback of about 650 students demonstrate that most of them – especially lower performing readers – profit from the rearrangement and that therefore a considered and theoretically-based typographical optimization fosters accessibility and inclusion concerning science and scientific literacy.

Kate Henson Jason Buell

Scaffolding Support for Student Modeling in Three Dimensional Assessment Tasks

A Framework for K-12 Science Education set forth an ambitious set of goals for reforming science education. Educators face significant challenges as they shift instruction and assessment practices to align. Framework aligned assessments must attend to all three dimensions and be grounded in the idea that students build understanding over time. This paper investigates the design and use of three dimensional assessments known as Phenomenon Based Item Clusters (PBIC), used with the Modeling Energy Flows learning progression in the context of high school biology and physics classes. We hypothesized that highly scaffolded items in the PBIC would support students in the open ended modeling and explanation items by reducing the cognitive complexity of those items and that students would use the components they selected in the scaffolded items in their models and explanations to demonstrate their understanding of energy flow to explain phenomenon. We found that students used the scaffolded items as reference for their models; however, students did not use the elements to explain the phenomenon as intended. Next steps include reevaluating our system of challenges to redesign scaffolds to specifically support students in the areas where they demonstrated the most difficulty. With continued refinement, assessment tasks, have the potential to support equitable three dimensional learning in schools and districts.

Ineke Henze-Rietveld Erik Barendsen

The agile educator: investigating science teachers' pedagogical capacity to design subject-specific up-todate citizenship lessons

Education is the key process for generating responsible, scientifically literate citizens. Modern science education is expected to provide young people with the basic knowledge, skills and attitudes necessary to participate actively in a multicultural, democratic and technology-infused society and to make informed decisions on controversial socioscientific issues. Indeed, adding elements of dynamic and often rapidly changing societal contexts has become an important ingredient of science education. More than traditional science teaching, this requires a high degree of agility in the teacher. This in-depth study explores the pedagogical agility of three Dutch science teachers through their pedagogical capacity (i.e. use of personal and instructional resources) to design up-to-date science subject-specific 'citizenship

lessons' in the context of a professional learning community. Research data was collected through teacher interviews. Qualitative data-analyses were performed using Atlas-ti. Common patterns and distinguishing features were found in the nature of the teachers' personal resources and instructional resources and the way in which resources were used to design the citizenship lessons. We present and discuss our findings in light of the emerging concept of science teachers' agility, in particular, elaborating on the unique combination of teachers' subject-specific pedagogical competences leading to the agility necessary for modern science education.

Sara C Heredia Michelle Lea Phillips

Exploring Boundary Spanning as a Theoretical Framework to Design for Science Teacher Leader Professional Learning

In this paper, we present an analysis of an initial design of a professional learning program for science teacher leaders. Science teacher leaders have been named as integral actors in the implementation of educational reform, yet as a field, we lack frameworks to understand and design for their professional learning. We present boundary spanning from organizational theory as a framework to understand how science teacher leaders interpret, filter, and translate resources to support the implementation of science education reforms in their local context. We used interaction analysis of video data to identify how key task and participant structures of the professional learning program supported boundary spanning and provide descriptions of this boundary spanning as it happened in practice. This presentation will be of interest to NARST members who support science teacher leadership and their professional learning to support the implementation of science education reform.

Benjamin C Herman Michael P Clough

University Biology Students' COVID-19 Decisions: The Interconnected Influence of COVID-19 Science Perceptions and Sociocultural Membership

Like all SSI, the COVID-19 pandemic requires engagement that involves scientific thinking and may vary across social groups. This investigation determined how COVID-19 science views and sociocultural membership associated with 475 university biology students' COVID-19 actions and mandate support. Hierarchical moderated multiple regression analyses demonstrated that higher levels of students' actions and support for mandates that mitigate COVID-19 associated with increased COVID-19 prevention knowledge and risk perceptions. However, being increasingly politically conservative significantly associated with lower levels of COVID-19 mitigating actions and mandate support. Confidence in the CDC and cognizance of science as an amendatory/revisionary process positively predicted COVID-19 mandate support. However, political orientation moderated the relationship between students' views about COVID-19 science and scientists, and their COVID-19 actions and mandate support. For instance, an increased confidence in the CDC held an important positive association only with very conservative students' COVID-19 mitigating actions. Among more politically conservative students, as opposed to liberal students, increasing confidence in the CDC and cognizance of amendatory/revisionary nature of science was a strong positive predictor of beliefs that COVID-19

mandates are justified. Implications discussed include the importance for helping students analyze how sociocultural membership, personal biases and trust in science interactively influence socioscientific decision-making.

Imogen Herrick Gale Sinatra

Using Augmented Reality (AR) to Bring the Past to Life in Informal Science Learning

A key mission for museums is to engage a large and diverse public audience in science learning (Macdonald, 1997). To that end, science museums attempt to use immersive technologies in entertaining, socially oriented, and innovative ways. An example is the use of augmented reality (AR) to overlay virtual objects onto the real-world (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001).We used a Design Based Research (DBR) approach to develop and test four features of an AR experience to promote place-based science learning in an museum setting. While quantitative differences were not found among conditions in knowledge gained, significant learning gains were seen from pre to post, illustrating the potential for place-based informal science learning. Incorporating AR technology into museum exhibits can update them with 21st tools to support visitor engagement in the learning experience. This research contributes to understanding of usability and logistical issues for different AR designs for a public, outdoor informal settings.

Imogen R Herrick Michael Lawson

Adjusting the Lens: Elementary Students Sharing and Learning about Climate Change through Photovoice

The largest Global Climate Strike in history was organized by youth, demonstrating students consider climate change a key issue impacting their futures. However, the field knows little about the climate change knowledge and experiences elementary students bring to the classroom. Thus, we conducted a photovoice and transformative experience informed study with 22 fifth-graders to explore how students understand climate change, whether engaging in a photovoice informed unit offers students a transformative experience, and if photovoice helps the teacher rethink the possibilities of elementary science education. Data sources include student photographs, reflections, photo-elicitation interview, TE post-survey, and transcripts of unit activities, along with teacher memos written throughout the unit and a teacher post-interview. Using qualitative and quantitative methodologies, findings indicate students have diverse perspectives on climate change, approach the topic through different orientations, and had a transformative experience by participating in the photovoice and transformative experience informed unit. In addition, preliminary analyses indicate the teacher gained a better understanding of ways to bring students prior knowledge and experiences into elementary science education. We recommend photovoice as a teaching and research methodology to help foster transformative experiences in science learning and to help teachers implement meaningful, personally relevant science education.

Cari F. Herrmann Abell Joseph M. Hardcastle

Exploring the Comparability of Multiple-Choice and Constructed-Response Versions of Scenario-Based Assessment Tasks As implementation of the Next Generation Science Standards moves forward, there is a need for new assessments that can measure students' integrated three-dimensional science learning. The National Research Council has suggested that these assessments be multicomponent tasks that utilize a combination of item formats including constructed-response and multiple-choice. However, little guidance has been provided for determining the relative value or cost effectiveness of those two formats. In this study, students were randomly assigned assessment tasks that contained either a constructed-response or a multiple-choice version of an otherwise equivalent item. Rasch analysis was used to compare the difficult of these items on the same construct scale. We found that constructed-response versions were more difficult than their multiple-choice counterparts. This difficulty was found to be partially due to the reasoning element in the constructed-response rubric. Students were more likely to recognize a clearly reasoned argument in a multiple-choice item than they were to create that reasoning themselves. The results also suggest that the difference in difficulty may have been exaggerated due to students not reading the questions as carefully as necessary and failing to earn points because they were responding to the wrong question perhaps due to the low stakes testing environment.

Lindsay Hetherington Justin S Dillon

Creative and Digital Pedagogies for Teaching Ocean Literacy: The Ocean Connections Project

The EU-Erasmus project 'Ocean Connections' aims to develop approaches to teaching Ocean Literacy through combining key ideas and practices from research streams in creative pedagogies and in the use of digital technologies, namely Augmented and Virtual Realities (AR and VR). The project identified some core educative principles derived from the research literature which were then explored in practice within 6 pilot projects, 2 each in England, Spain and Denmark. At the heart of the Ocean Connections project is a material-dialogic theoretical perspective that draws on new materialist theory to understand learning about the Ocean as a relational, emergent process. We present this theoretical framework and our rationale for its use; and the educative principles on which the pilot projects were based. We then present findings from our mixed-methods analysis, drawing on questionnaires, interviews with pupils and teachers, and field observations to illuminate how the educative principles manifested during the projects. Findings show that some key practices such as modelling, and student-led learning/production of and with technology can aid the enactment of a combination of digital and creative pedagogies for teaching ocean literacy. It also showed the potentially important role of creative pedagogies in fostering ethical, activist dimensions of ocean literacy.

Shari E. Hiltbrand Mihwa Park

An Exploratory Study to Develop a Framework of Middle School Science Giftedness in NGSS Era

Science giftedness exists at the intersection of intellectual academic ability in science and psychosocial characteristics of gifted individuals (Feist, 2013). Characteristics of science giftedness have not been fully investigated for identification purposes. This exploratory study seeks to fill a research gap by developing a framework of science giftedness and set of distinct and discernable characteristics of science

giftedness. Science giftedness perceptions were gathered from middle school science and gifted teachers from a variety of school types, locations, and socioeconomic settings, as well as science education and giftedness/gifted education researchers using a qualitative Grounded Delphi Method (Howard, 2018; Päivärinta et al., 2011). A science giftedness framework and characteristics were formed which can be used by educators to find science gifted students and provide more appropriate support for those students. By filling a research gap, this proposed science giftedness framework and characteristics provides educators and researchers a guide for identifying gifted science students during the formative middle school age thereby providing opportunities to engage identified students in advanced science and scientific inquiry opportunities and facilitating rising 21st century gifted scientists to reach a level of eminence in their field.

Benny Mart Hiwatig Joshua A. Ellis

Understanding the Relationship between Context and Content Integration

Despite its presence in policy documents and classrooms, defining integrated STEM education has been a challenge, delaying the development of observation protocols to understand how STEM education is being practiced in K-12 classrooms. Our work uses a new 10-item observation protocol designed for integrated STEM teaching in K-12 science and engineering classrooms. Using a database of over 2000 video-recorded classroom observations of integrated STEM instruction, this related paper set provides new research that allows the project team to begin to assess and understand current methods of implementation of integrated STEM in K-12 science classrooms. This related paper set includes a series of four studies that highlights how the new observation protocol can be used to understand current classroom practice as it relates to current reform efforts, including comparisons across different classrooms, explorations related to the nature of integration, and the importance of mathematics integration. Our findings suggest that there is much work to be done related to K-12 integrated STEM instruction. The collective knowledge gained from this work can help researchers and teacher educators design professional development for in- and pre-service science teachers to support them in their efforts towards successfully integrating STEM to meet current science education reform efforts.

Georgia W Hodges Kayla P Flanagan

A Mixed Methods Study of Serious Game Design Heuristics that Support Elementary Science Learners

Serious educational games (SEGs) may have particular utility in elementary science classrooms, where teachers are trained as generalists. This study stems from a larger project that created a SEG designed to teach the body systems through immersive gameplay. Prior studies (Authors, 2020) found that students (n=232) who experienced this gaming experience significantly outperformed students who participated in a quality comparision condition. This convergent mixed methods study was designed to deeply explore how and when learning takes place during gameplay (n=177) through analysis of 150 assessment items embedded within gameplay. Quantitative methods including Analysis of Variance and latent Dirichlet allocation were used to measure student growth within and throughout gameplay. Qualitative methods, including inductive and deductive content analysis, were conducted on pre- and

post-test constructed responses and embedded gameplay data. Findings provide specific examples of game design heuristics that support elementary science learners in generating evidence based explanations about phenomena explored. These in-game design heuristics include: the use of feedback mechanisms that provide students with opportunities to practice skills more than once; the use of a deeply constructed narrative; and the incorporation of multiple visualizations of a phenomenawere all linked to science learning.

Dorothy Holley Soonhye Park

Science Teachers Who Stay: Factors Contributing to Teacher Retention

A descriptive and explanatory study investigated factors that contribute to high school science teacher retention. Specifically, this study explored how mid and late career high school science teachers in a southeastern state in the US describe influences and cope with challenges that encourage them to remain in the teaching profession. Qualitative content analysis using Bandura's social cognitive theory of factors (N=147) that have encouraged teachers to remain in the profession were Personal (79.1%), Environmental (7.5%), and Behavioral (13.4%) in nature. Themes describe the importance of student success, teacher success, and teacher control on retention decisions. Findings of this study reveal the most frequent coping strategy cited by experienced science teachers when they considered leaving the profession is transfer schools.

Ene Ernst Hoppe Katia Bill Nielsen

APPLYING ART-BASED METHODS TO TALK WITH CHILDREN ABOUT NATURE, TECHNOLOGY AND HEALTH

In this paper, we explore the potential of art-based methods as a way of talking to children about science. In science education research these methods has received limited attention and therefor we seek to explore the potential of these methods. The paper reports from a ten-year longitudinal research project in Denmark using qualitative methods as workshops, ethnographic fieldwork and interviews. The data in this paper draw on the empirical material produced through the workshops facilitated in 5th grade. Four activities was done with the children and this paper emphasis one activity focusing on how children relates nature, technology and health to themselves and the surrounding world. Using art-based methods provides participants with new ways to engage and communicate through performative, creative, and visual approaches. An advantage when talking to children about science where barrires as language and less knowledge to the terminology of science. The results shows how a need for providing children with different ways to express enable different kinds of perceptions to display. This diversity allows knowledge to be more than oral and written language.

Douglas Lee Hoston Richard Lamb

John Henryism: Exploration of Physiological Examination of College STEM, Cumulative Trauma, Allostatic Load.

The purpose of this study is to examine allostatic load and John Henryism within post-secondary science, technology, engineering, and mathematics (STEM) learning environments through identified cumulative traumatic stress. The physiological impact of prolonged stressors has deleterious health effects on historically underrepresented students. The researcher administered a stress inventory survey which generated elevated responses. These elevated responses will be examined through personal narratives and measured against physiological markers for noted physiological responses. The sample will consist of medical school post-baccalaureate students in a research-intensive, public university in the Northeast. The researcher will examine outcomes of physiological measures and coded interviews. The researcher will examine physiological markers and outcomes through Pearson's correlation coefficient based on survey-informed personal narrative physiological responses examined through the lens of Richard Lamb's psychological allostatic load. Keywords: Allostatic load, John Henryism, Historically Underrepresented, STEM, Post-secondary

Pei-Ling Hsu Dina Thomason

High School Students' Emergent Positions from Science Internships

Learning science in authentic settings, such as science internships in university laboratories, has been suggested as a great way to enhance students' scientific knowledge and skills, views on the nature of science inquiry, and aspirations for pursuing science careers. However, little research was done to study how high school students may position themselves in science internships while working at the elbow of scientists. According to positioning theory, how students view and position themselves can greatly influence how they participate in educational activities. Thus, the purpose of this ethnographic study is to investigate high school students' positions emerged from their interactions with scientists in science internships. By analyzing students' cogenerative dialogues on their internship experience, we identified ten categories of high school students' positions emerged in science internships. Our findings also discuss how each science laboratory team made unique and different contributions to high school students' positions identified in this study, as students learn how to research and experiment to answer scientific questions in an authentic science learning environment.

Peter Hu Ling L. Liang

Examining NGSS Scientific Practices in K-12 Science Classrooms

The Next Generation Science Standards (NGSS) call on teachers to better develop students' understanding of scientific core ideas and concepts while engaging them in scientific practices. In this study, we used an observation protocol (IONIC – ICAP to Measure by Observation NGSS Scientific Practice Implementation in the Classroom) based on the Interactive-Constructive-Active-Passive (ICAP) framework to examine the quality of student engagement with these practices in K-12 classrooms, compared across grade bands and subjects. With a second-order factor model, 188 videos of instruction in science classrooms were evaluated with the observation protocol. It was found that students in

Middle school classrooms were most likely to be engaged at the Active level, while Elementary students were most often engaged in the Constructive level or higher, in multiple practices. Few differences in practices were found across subjects. Implications and limitations of the study will also be discussed.

Yuxi Huang Hatice Ozen Tasdemir

Video-based Instruments as Assessment Tool in Science Teacher Education: A Systematic Literature Review

With the development of technology, video-based instruments are increasingly used as an assessment tool in science teacher education. Compared to paper-pencil tests and classroom observation tools administered before to assess science teachers, video-based instruments could simulate the complexity of classroom environment and many video-based instruments were time-saving. The popularity of video-based instruments calls for a systematic review. After conducting search of empirical articles in four commonly used databases in education and reference searching, we identified 20 articles for review. Further analysis examined the characteristics of the research, characteristics of the videos, and validity and reliability evidence the existing video-based instruments provided. Our research identified the current research gaps of using of video-based instruments as assessment tool and suggested future research directions.

Pamela Huff Gail Jones

The Challenges of Teaching in Charter Schools and How They were Overcome During the COVID-19 Pandemic

COVID-19 pandemic restrictions presented teachers, students, and parents with unique challenges that were met with creativity, flexibility, and stamina. As a part of a larger study, this study utilized interviews to examine charter school science teachers' online teaching in response to COVID-19. Specifically, this study explored teachers' strategies, technologies and resources, student learning perspectives, and emotional and physical health responses with a semi-structured interview. There were significant challenges to providing online teaching due to technology constraints involving hardware, software, and internet connectivity. Additionally, teachers were ill-prepared for online teaching due to the lack of training, professional development courses, and comradery and communication among peers. Although teachers suffered emotionally and physically, they were creative and resilient as they struggled to develop novel pedagogical resources that not only worked in the online setting but also inspired students.

Ally Hunter Heather Griller Clark

Examining the STEM career interest of juvenile justice youth using the Social Cognitive Career Theory.

Youth involved in the juvenile justice (JJ) system are some of the most vulnerable and marginalized learners in our country. They experience a general lack of access and exposure to high-quality science,

technology, engineering, and math (STEM) instruction, career exploration, and employment opportunities. This prevents already marginalized learners from attaining the literacy necessary to flourish in an increasingly STEM focused employment landscape. The purpose of this study was to explore the STEM knowledge and career interest of JJ youth using the social cognitive career theory (SCCT). We find that in general, JJ youth have moderate STEM self-efficacy and at the same time have fairly low performance on below grade level STEM competency items, and low perceptions of STEM support both inside and outside the facility. We also find JJ youth to have a variety of interest in, and knowledge of, STEM careers, however limited this knowledge may be. We posit a framework for the design and assessment of STEM career curriculum for JJ youth to improve the STEM outcomes for JJ youth. Use of SCCT is key to understanding the disparities that exist in STEM and provide a common perspective for explaining these disparities and designing interventions to foster STEM justice.

Ally Hunter Melissa Zwick

Case Study Pedagogy as Inclusive Pedagogy: Entry Points for STEM Faculty to Build Inclusive Classrooms

As higher education calls for more inclusive teaching practices in STEM undergraduate classrooms, instructors need explicit, tangible ways to incorporate inclusive pedagogies into their classrooms. The purpose of this study was to align a known framework for inclusion (critical inclusive pedagogy) with a well-adopted framework for STEM teaching (case study pedagogy). We show the alignment of the two pedagogies and the resulting student perceptions when three case studies were implemented in two undergraduate biology classrooms. After exposure to the case studies, students were asked to report their beliefs about the role of the narrative, the pedagogical features used during the case study, and their feelings of inclusion. On average, students agreed that the role of the narrative and the pedagogical features were important to their learning and that the case studies created feelings of inclusion. When students had strong perceptions that the story was the key to learning, they also had strong feelings of inclusion. When the story had diverse characters in diverse settings this relationship was especially strong. These findings provide insight into how case study pedagogy can be developed and implemented and serve as an entry point for faculty to create inclusive classrooms.

Roberta Hunter Irene S. Bayer

The power of virtual platforms to support teacher learning and community development for urban outdoor science teaching

In the U.S. recent widespread adoption of the Next Generation Science Standards (NGSS) has required deeper knowledge and different instructional practices from all teachers. The ability to take up NGSS-aligned practices is particularly challenging in under-resourced urban school contexts. Our work has centered on developing sustainable partnerships between teachers and informal science educators (ISErs) to support deeper understanding of how to provide outdoor experiences which are NGSS-aligned and teaching that is specific to their place and the cultural and social needs of their students, making use of several frameworks, including place-based, design-based implementation research, culturally responsive teaching and heads-on, hands-on, hearts-on (3H). In this related paper set, we consider the

work ISErs do with other educators, students, and the general public, and how these contribute to their identity (Paper1); evaluate theoretical frameworks as interpretive lenses on such partnerships (Paper2); address how we made use of a virtual environment to establish professional community and "set the stage" for summer and school-year learning (Paper3); investigate the program's impact on teachers questioning and subsequent planning intentions (Paper4); address how specific contextual factors shaped the ways the program was taken up and our leveraging of these factors to support participant learning (Paper5).

Todd L. Hutner

An Exploratory Study of the Epistemic Goals of a First-Year Science Teacher

Recent efforts to reform science teaching have moved beyond engaging students in scientific inquiry to students engaging in scientific practices. Underlying the definition of practice is the acknowledgement that students are participating in the community of science which has developed a set of practices based upon epistemological commitments of members of the community. Science teachers play an important role in shifting from scientific inquiry to scientific practices and helping students develop the epistemological understanding undergirding those practices. Beyond teachers having epistemological knowledge, teachers must also hold goals to foster their students epistemological understanding. The purpose of this paper is to explore the epistemic goals of a single first-year biology teacher, Jon. Primary data is 32 interviews with Jon, conducted weekly during the school year. Secondary data are classroom observations, and copies of lesson plans and student handouts Jon created or used during the year. Initially, Jon held epistemological goals that partially overlap with the epistemological commitments underlying the Framework. As the year progressed, Jon began to pull back from his epistemological goals. By the end of the year, Jon had disengaged from his epistemic goals and acquiesced to the other biology teachers in terms of his instructional approach.

Yohan Hwang Kongju Mun

Exploring of environmental engineering college students' social responsibility and problem solving through the SSI project

This study introduces the achievements of environmental engineering students who participated in an SSI based educational program for strengthening social responsibility called the ENACT project and aims to explore changes in social responsibility and their SSI problem-solving progress. 28 college students participated in this study and we collected students' writings and personal recordings through the online learning portal we developed. We also surveyed to measure students' social responsibility before and after the ENACT project. We found that students' social responsibility improved and students suggested the appropriate technology to solve the problem in developing countries through ENACT project. Based on these results we will discuss science education for engineering students to enhance their understanding of SSIs and social responsibility.

Natalie L Hyslop John Holliday

Evaluating Evidence-Based Practices Influencing Graduation and Participation in the STEM Workforce and Graduate Programs

In 2015, the National Science Foundation funded a scholarship program at our institution to help increase the STEM workforce by recruiting, mentoring, and supporting academically talented, low-income students through degree completion, assistance with graduate school admissions, and assistance with placement in the STEM workforce and/or graduate school. To address these goals, evidence-based practices including peer and faculty mentoring, success workshops, frequent solicitation of scholar feedback about support needs, regular evaluation of scholar progress, individual interventions, and undergraduate research experiences were used. The data showed students in the program had a marked increase in STEM degree retention, completion, and entrance into the STEM workforce and/or graduate programs. At the completion of the program, 88% of the scholars had either graduated with or were still enrolled in a STEM program. Of those who graduated, eleven were accepted directly into STEM Ph.D. programs and all students who graduated with an A.S. degree continued to a STEM B.S. degree. Additionally, >90% of scholars reported the scholarship funds allowed them to devote more time to school and undergraduate research, which assisted greatly with student success. This proposal discusses the strategies used in the program that led to scholar success.

Amal Ibourk Roxanne M. Hughes

Counterstories of Black Women About What it Means to be a STEM Person

Both K-12 schools and STEM disciplines are embedded in White supremacy and exclusion making it that much harder for Black women to maintain an interest and sense of belonging in schools as well as STEM. In this study we give voice to two Black women: one who is currently entering graduate school as an English major with a focus on Science Fiction writing and the other who is finishing her final year as an Engineering major. Both of these women were able to navigate through their predominantly white K-12 systems and find a STEM identity that was supported through various stories of resilience. Then in college, both had moments of self-doubt that led to one switching her major to English (Sara) and the other finding a renewed commitment to engineering because she found relevance to her racial and gender identity (Kayla). Neither woman would define their experience as thriving in STEM but both were able to maintain a STEM identity despite it not being recognized as such (E.g. Science fiction writer and Black women's maternity health) by STEM institutions.

Bashirah Ibrahim Lin Ding

How Do Students Make Sense of Simultaneous Synthesis Physics Tasks?

We investigated students' sensemaking of the situations presented in simultaneous physics synthesis problems. Such problems involve a series of events that require concurrent application of multiple concepts. We recorded the students' eye fixation durations on each problem diagram when they silently reflected on how to tackle each task and when they verbalized their problem-solving strategies respectively. We also looked at their verbal descriptions of their problem-solving strategies. Results

indicate that the students had a longer fixation duration on parts of each diagram that require reading given information than on those that require generating new information. Further, they predominantly used one concept to solve each problem. In most cases, the concept was irrelevant. Moreover, they tended to either invoke one intermediate variable or use the quantitative information given in the problem text for problem-solving. According to the eye-mind framework, these outcomes indicate that the students' cognitive efforts were mainly at the level of processing given information. This study suggests that the spatiotemporal concurrence of multiple events in simultaneous synthesis tasks may have affected students' proper sensemaking.

Marie Irmer Dagmar Traub

Measuring the effects of scaffolds in a video-based learning environment for pre-service biology teachers

To foster diagnostic competences in university education for pre-service teachers, video-based tools can be an effective way to practice skills for diagnosing. To diagnose in classroom situations pedagogical content knowledge (PCK) has to be applied in diagnostic activities (DA). Scaffolds can be an effective intervention to support learners, especially with little prior knowledge, to achieve a learning goal. In an intervention study with pre-post-test-design using a video-based learning environment, the effects of scaffolds on the diagnostic competences of 57 pre-service biology teachers were investigated. Two types of scaffolds were developed: generic scaffolds focussing on the diagnostic activities (DA-scaffolds) and context-specific scaffolds providing additional information on aspects of biology-specific instructional quality (PCK-scaffolds). The participants were assigned to one of the four groups (PCK/PCK+DA/DA/control) depending on what type of scaffolds they received in the intervention. The PCK-group and the PCK+DA-group showed statistically significant higher diagnostic competences in the post-test than in the pre-test. For the DA- and the control group no significant improvement can be reported. The diagnostic competences of pre-service biology teachers can effectively be fostered by including PCK-scaffolds in the video-based learning environment. A teachers' PCK seems to be the base of a successful diagnosis in a classroom situation.

Michal Haskel Ittah Elon Langbeheim

Applying epistemic heuristics to characterize student reasoning about mechanisms with computational tools

Computational tools are commonly used when introducing mechanistic explanations of phenomena such as diffusion, heat conduction or ecological balance. In this symposium we use Krist, Schwartz and Reiser's (2018) notion of "epistemic heuristics" that guide learners when looking for, critiquing or revising mechanistic explanations. We use these heuristics to examine what kind of takeaways were evident in students who used a variety of computational tools, each with a different emphasis. From tools that emphasize model construction, through participatory simulations and interactive maps, we show that students form a variety of epistemic beliefs about the mechanisms they explore. Our findings suggest that students use these epistemic heuristics for reasoning about a variety of very different phenomena fruitfully. Students may use it for building models for explaining correlative

connections or for criticizing models. Nonetheless, they might need more scaffolding especially when the discussed phenomenon is complex, when students tend to use centralized reasoning or when the phenomenon involves sociological aspects.

Lama Z. Jaber Shannon G. Davidson

Epistemic Empathy: A Resource for Responsive Teaching

While research continues to provide evidence for the affordances of responsive teaching in science classrooms, there is yet much to understand about what supports teachers to be responsive to students' contributions and experiences during instruction. In this work, we argue that teachers' epistemic empathy—their capacity to tune into and appreciate learners' cognitive and emotional experience in constructing, communicating, and critiquing knowledge—can serve to promote their responsiveness. Drawing on data from a STEM teacher education program, we show how epistemic empathy can be leveraged as a pedagogical resource to stabilize preservice teachers' attention and responsiveness to student thinking as they navigate various pushes and pulls in their efforts to enact student-centered instruction. Our findings contribute to research on teacher education by nominating epistemic empathy as part of the process of responsiveness and by highlighting the need to cultivate epistemic empathy as a target for teacher learning to support their enactment of responsive teaching.

Gabrielle Jablonski Anna S. Grinath

Becoming a Scientist: Exploring How Critique Supports the Development of Undergraduate Students' Science Identity

The development of a disciplinary identity is an important goal for undergraduate science education as it is theorized to increase student persistence and retention in the sciences. However, research is needed to identify and describe the specific types of experiences in undergraduate science education that best support students' science identities. Through conducting a multiple, descriptive case study we aimed to qualitatively characterize how undergraduate students perform critique in different undergraduate contexts, and how their performance of critique influenced how they recognize themselves and are recognized by others in the science community. This study took an uncommon approach of operationalizing the recognition component of science identity by drawing on ideas of disciplinary accountability and authority. By taking this novel approach when analyzing students' critiques and the narrations of their science identities, we found that while students were often being implicitly positioned by their peers as having the disciplinary authority to critique the primary literature, these students did not connect their engagement in critique as being influential to the development of their science identities. This research has implications for informing undergraduate instruction that supports students developing science identities and beginning to recognize themselves as integral members of a scientific community of practice.

Ashley N. Jackson Darrell Allen

Don't forget about the LGBTQIA+: Toward a more robust queer theory in science education

We situate this paper within a society where people believe and say things that are anti-LGBTQIA+. Reflecting on our Black queer identities, we seek contribute to this years theme by showcasing ways to disrupt science education while centering LGBTQIA+ persons. In this evidence-based position paper we call for a more robust rendering of queer theory within the NARST community as a means of accountability to one another and an avenue to build scientific literacy around gender, race, sexuality, and class. Within this paper we discuss definitions of queer theory and its presence within science education research. We then expound on the tensions that arise in using queer theory for science education research and propose recommendations for the larger NARST community that center utilizing "queer" as an adjective as a means to understanding larger resistance projects. Keywords: Queer studies, STEM Education, Queer theory

Iesha Jackson Tina Vo

Investigating graduate student and instructors' course experiences "Teaching and Learning Science for Social Justice"

Few guidelines exist for science education within higher education contexts. Given that graduate student instructors can make up to 10-20% of the teaching population in research-focused universities (Friedman, 2017), graduate instructors need to understand social justice and equitable teaching practice. This need increases when considering teaching and learning within science, as NSF (2019) reports the continued underrepresentation of women and minorities in STEM. One way to support more equitable science practice is by providing opportunities for science-oriented graduate assistants to learn and apply Critical Race Theory (CRT) within the context of science towards social justice. This can frame an approach to science teaching and learning that centers systemic racism and power as essential to understanding to analyze and act against inequity in science education. This research describes the development of an educational course for science and science education grad students and the experiences of graduate students while engaging in the course "Teaching and learning science for social justice."

Jennifer Jackson Jonathan D. McCausland

Exploring the prevalence of whiteness within science education using duoethnographic methods

Currently, the field of science education is experiencing a crisis. It is our belief that as fewer POCs matriculate into the teaching profession, the field at large continues to lack diversity. Since the educational system continues to reflect mostly characterizations of whiteness, the norms of the profession have been directly impacted. Therefore, for this study we wanted to develop a deeper understanding for how our racial identities as a Black woman and as a white man influenced our experiences within the context of science education. To analyze this issue, we applied Critical Race Theory (CRT) as an analytical framework to a series of racialized narratives constructed while completing

a duoethnography. Using this type of methodology required for us to share our personal perspectives through written responses and verbal communication throughout the analysis phase. While each of the racialized narratives related back to several CRT constructs, we also utilized an additional CRT theme known as Whiteness as Property to reveal evidence of white supremacy within the collected data. Finally, this proposal serves to bring attention to the existing problem that there continues to be an extremely large presence of whiteness within the science education field.

Sophia Jeong Kathryn M. Bateman

Re-thinking Science Education Using Non-linear Theories: Implications of Posthumanism on Ethics, Policy, and Practice

Science education has historically been valued for its ability to influence economic power and global standing in the world. As such, discourses in science education in the United States are entangled with economic and political forces through its connection to skilled worker creation supporting industrial and technological dominance. These connections create tensions between what science industries, government agencies, and education see as ethically imperative. In this theoretical paper, we argue the value of agential literacy as a way to move beyond the limitations of science education as a means for political and economic dominance to science education as a tool to reimagine humans' place in the world as entangled beings. To this end, we apply nonlinear theories to show a process for re-thinking science education and discuss the implications of posthuman ethics on science teaching and learning.

McKenzie N Jevnikar Colette E Pappas

Undergraduate Biology Student Perceptions of Wellness Interventions

Recently, there has been a surge in educators incorporating wellness activities into their classrooms, likely due to the increase in mental health issues related to the pandemic. While the surge in wellness interventions, such as student check-ins, seems to be beneficial based on faculty impressions, how do students perceive the efforts of faculty to check in with them throughout the semester? Do student demographics have an impact on student perceptions? A What Is Happening In This Class (Fraser et al. 1996) questionnaire was used to assess student perception of wellness interventions. Forty-eight students responded to statements on a scale of 1-5 (1-Almost Never to 5-Almost Always) and 31 students explained why each statement received that rating. 83% of students noticed and responded positively to the wellness interventions in the course (p<0.001). Ratings did not significantly differ among students of different academic years (p=0.1854), gender identities (p=0.9768), or race (p=0.9649). These findings show that students do appreciate the prioritization of wellness in the classroom and further support that being cared for is a fundamental human need that does not vary across demographics. Therefore, student mental health wellness check-ins should be implemented by all educators in all courses.

Samantha Jewett Anton Puvirajah

Examining the Nature of Canada's Scientific Literacy Through COVID-19 Tweets

Scientific literacy, or the ability to critically evaluate, understand, and make decisions regarding scientific information, is the goal of science curriculums globally. Scientific literacy is essential because it enables citizens to assess information and make informed decisions regarding scientific issues that affect their lives. The internet has become the primary source to access, disseminate, and discuss scientific information in recent years. Internet usage and science communication are complex social phenomena that researchers are still trying to understand. Our exploratory case study seeks to add more understanding to this phenomenon. We employed content analysis using a mixed-method research design to investigate the research question: What is the nature of people in Canada's scientific literacy usage on social media when navigating, discussing, and disseminating information about the COVID-19 pandemic on Twitter? By examining 1000s of tweets originating from Canada discussing the COVID-19 pandemic, we learned about how scientific literacy is used on Twitter and how different factors affect this usage, including time periods during the pandemic and the topic being discussed. Our research can inform future studies in various fields, including science education, science communication, and health communication.

Natasha H. Johnson

Building Bridges: An Intervention to Improve Academic Outcomes for Underrepresented "Minority" Students in General Chemistry

At many universities in the United States, introductory chemistry serves as a gatekeeper to careers in the sciences. This is a significant barrier for underrepresented "minority" students who consistently underperform their majority counterparts in the general chemistry coursework. The purpose of this study was to investigate the impact of an academic intervention in the context of a summer bridge program and learning community on the academic outcomes of students enrolled in a freshman chemistry course at a large, public university. Students were introduced to metacognitive learning strategies shown to boost student motivation and learning outcomes in a variety of academic settings. Additionally, the project incorporated chemistry instruction through camp and learning sessions. Data collection consisted of demographic questionnaire, surveys, and interviews. Particapants demonstrated improved academic outcomes during the first semester of of college as measured by course grades and first semester grade point average. Findings have implications for future research.

M. Gail Jones Katherine Chesnutt

Assessing Elementary Students' Science Interests and Career Aspirations

The present study addresses the lack of instrumentation for assessing career aspiration factors for elementary students. The purpose of this study was to research and validate such an assessment. Educators have worked for decades to isolate and measure the factors that contribute to science,

technology, engineering, and mathematics (STEM) career decisions. The issue is particularly salient for initiatives designed to increase the number of women and ethnic minority groups that are underrepresented in these fields. However, there are limited instruments available to measure factors that contribute to students' STEM career aspirations, particularly for elementary students. The internal validity of the NextGen Scientist Survey- Elementary was investigated using confirmatory factor analysis. The results found a five-factor solution was the best-fitting model (Science Expectancy Value, Tangible Science Experiences, Intangible Science Experiences, Future Science Task Value, and Family Science Achievement Values). Results showed that the NextGen Scientist Survey is a valid assessment to measure factors related to career aspirations for elementary students.

Victor Kásper Shannon G. Davidson

"Kinda awful.I spent a lot of time crying":Attending to the Emotions of PSTs of Color

As the demographic and cultural disparities between K-12 learners and teachers continue to widen, the recruitment and retention of students of color into teacher education programs remain a critical and pressing issue. Particularly in STEM-focused teacher education programs where students of color must navigate two predominately white spaces, preservice teachers (PSTs) of color report numerous racist, marginalizing, and isolating experiences. These experiences can raise intense emotions and feelings that PSTs of color must navigate and wrestle through at historically white institutions. Here we investigate the feelings and emotions experienced by one PST of color, Camie, who faced myriad racialized and marginalizing experiences in her teacher education program. Our findings highlight three themes that significantly shaped Camie's experiences and learning in the program: (1) her experiences of being "othered" due to her race and gender, (2) the tension in choosing between advocating for herself or speaking up and her search for emotional support, and (3) her desire to be the STEM teacher she never had. Our analysis points to the need for teacher education programs to listen to, attend to, and support PSTs of color's emotional experiences alongside their disciplinary and pedagogical learning.

Sami Kahn Janet Vertesi

The Impact of Online STEM Teaching and Learning During COVID-19 on Underrepresented College Students' Self-Efficacy and Motivation

Women, minorities, first-generation, and low-income students face considerable barriers to STEM education leading to their underrepresentation in STEM fields. Ensuring that underrepresented students develop strong self-efficacy and motivation in STEM during the college years is key to addressing the "leaky" STEM pipeline. To determine whether the rapid shift to online teaching and learning during COVID-19 exacerbated or mitigated inequities for college-level STEM students, we examined correlations between demographic and sociocultural factors and students' self-assessments on indicators of self-efficacy and motivation. Our findings suggest that students from underrepresented groups were differentially negatively impacted by the shift to online STEM teaching and learning, particularly insofar as access to study spaces, the internet, and peers. However, we found that the loss of traditional laboratories was not particularly impactful on any students' motivation or self-efficacy,

regardless of the courses' levels of dependence on such labs, as students were generally more impacted by concerns about family members' health and loss of social and structural supports than academic experiences. We discuss these results in light of psychosocial theory and suggest pedagogical and structural changes that can support more equitable outcomes in online and in-person college-level STEM education.

Gamze Karaer Macid Ayhan Melekoglu

Science Instructional Practices: Comparison of Two Strategies for Students with Learning Disabilities

The aim of this research is to design a program that facilitates the process of perceiving science texts of students with Learning Disabilities (LD) and to evaluate the effects of reading comprehension skills of LD students. Within this program, effectiveness of two science teaching modules were evaluated on six middle school students with LD who study in inclusive education classroom settings. This research was designed by using alternating adapted treatment model, which is one of the comparative single subject research methods. Independent variables of the study; science teaching Module-I and Module-II designed by using activity-supported (Module-I) and non-activity-supported (Module-II) graphic organizer strategies. The level of reading comprehension skills of the students is the dependent variable. Across average six sessions of intervention, all six students demonstrated improved performance on dependent variables with both treatment modules. All students demonstrated at least %80 average accuracy in Module-I treatment conditions earlier than Module-II treatment conditions. Although participants obtained criteria for reading comprehension of science texts in Module-I faster than Module-II, duration time of the interventions took more time in Module-I than Module-II.

Jessica Karch Ira Caspari

Student In-The-Moment Learning in LA-Facilitated Interactions in Undergraduate Chemistry and Physics Courses

To develop global scientific literacy, equitable pedagogical practices and a theoretically grounded understanding of in-the-moment learning are critical. One promising practice is the learning assistant (LA) model. Implementing LAs in large-enrollment lecture courses has had a positive impact on various measurable student outcomes, particularly for marginalized students, including improved course grades, decreased Drop/Fail/Withdraw rates, and conceptual knowledge acquisition. However, little is known about the nature of in-the-moment learning that leads to these outcomes. We sought to answer the research question: How does student in-the-moment learning progress in interactions facilitated by an LA? Videos of small-group interactions with LAs (n=19) were recorded in remote introductory physics and chemistry courses at two institutions. To analyze in-the-moment learning, we used practical epistemology analysis, which operationalizes learning as noticing and filling gaps, i.e., things that need to be made intelligible, with relations, i.e., pieces of knowledge or actions that are immediately intelligible. We found three patterns that trace the different ways LAs do or do not pick up on student ideas when opening gaps in order to to (1) advance students forward in the activity, (2) deepen

conceptual understanding, and (3) facilitate mutual understanding. Implications for theory and practice will be discussed.

Fatma Kaya Preethi Titu

An Online Professional Development Community (APTeach): Teacher Perception and Practice

APTeach is a case study of an online, national, and large-scale PD community for teachers that encourages regular collaboration and reflection to improve their teaching practices. Teachers have the option to join the synchronous online meetings and/or asynchronous text chatting to discuss issues in their practices, share their ideas, and assist each other, leading to the diffusion of successful teachers' practices. The purpose of the study is to understand teacher perceptions toward APTeach and how their participation in APTeach can influence their practices. The data collection consisted of 31 semistructured Zoom interviews in the Fall 2020 Semester. The coding strategies of the first and second cycles (Saldana, 2013) were used to analyze the interview transcripts. Teachers enjoyed interacting with and learning from other teachers who have similar interests and goals via the synchronous teacherdriven workshops. The present study also showed that many teachers used ideas and/or resources from other teachers in APTeach to enhance their teaching practices. AP Chemistry teachers in APTeach had mutual engagement and created a shared repertoire toward reform-based teaching practices.

Fatma Kaya Lisa A. Borgerding

Preservice Science Teachers' Implementation and Self-Efficacy About The Science And Engineering Practices

The purpose of the study is to understand how a science methods course changes preservice secondary science teachers' (PSTs) implementation and self-efficacy regarding the implementation of individual science and engineering practices (SEPs). Eleven PSTs enrolled in a secondary science methods class participated in this study. Interviews, an open-ended questionnaire (OEQ), video-recorded microteachings, and field observations were data sources in this study. First and second cycle coding strategies (Saldaña, 2013) were employed to analyze the data. Findings from this study showed that PSTs had difficulty differentiating between Practice 6 (Constructing Explanations and Designing Solutions) and Practice 7 (Engaging in Argument from Evidence), and several participants decreased their self-efficacy regarding the implementation of Practice 7. Similarly, the PSTs had difficulty distinguishing Practice 8 (Obtaining, Evaluating, and Communicating Information) from other practices such as Practice 3 (Planning and Carrying Out Investigations) and Practice 4 (Analyzing and Interpreting Data). Many PSTs implemented Practice 2 (Developing and Using Models), Practice 3, and Practice 4 in their teaching. The vast majority of the participants stated microteaching activities and preparing lesson plans were the important course elements that positively impacted their self-efficacy regarding the SEPs.

Ruveyde A. Kaya Jennifer Schellinger

Learning to Care for Students as Science Sensemakers: Preservice Elementary Teachers' Noticing and Epistemic Empathy

The purpose of this study was to explore the epistemic empathy employed by elementary preservice teachers(PSTs) through a teachers' noticing lens as they were asked to analyze elementary students' discussions of scientific phenomena in video analysis tasks. We explored how PSTs noticing shifted and informed the development of epistemic empathy across a science methods course. The data used for this examination included 10 PSTs' video reflections across the semester-long science methods course. Using an asset-based approach, we found that PSTs noticed students' ideas and sensemaking processes when guided with effective prompts; in contrast, they became more inclined to noticing focus on teachers and instructional methods and learning context as the semester progressed. Among PSTs, we found that their noticings of student learning and teaching aligns with markers of epistemic empathy that is important if PSTs are to realize their own potential to leverage students' ideas in instruction that positions students as sensemakers in science.

Sibel KAYA Nurullah Eryilmaz

How do immigrant students' self-theories affect PISA 2018 science achievement in three Anglophone countries?

This study proposes a model for the relationship between immigrant students' self-theories and science achievement by considering the impact of growth mindset, resilience, and effort. The study focuses on the PISA 2018 data in three countries: Australia, the United Kingdom, and the United States. Structural Equation Modelling is used to examine the interplay between self-theories of immigrants and their science achievement. The sex of the students and their socioeconomic status were used as covariates. Data analyses revealed that growth mindset was positively related to science achievement for both non-immigrant and immigrant students, and it had the strongest effect among all of the self-theories. Resilience was positively related to science achievement for immigrants in the US, and effort was positively related to science achievement for immigrants in Australia. The mediating role of effort between growth mindset, resilience, and science achievement could not have been confirmed. Implications regarding these findings will be discussed.

Shakhnoza Kayumova Akira Harper

Pedagogical Moves That Support Coordinating Communication and Co-Authorship in a Multilingual Science Classroom

Participating in science and engineering practices and sense-making in a classroom context requires cognitive and affective engagement in local activity systems and communication and coordination among all participants involved. The study was guided by the following research questions: (i) what promoted and sustained communication and coordination of sensemaking among multilingual students? (ii) what kinds of pedagogical moves were consequential in positioning multilingual students

as co-authors and epistemic agents within science and engineering activities? Our findings showed that the successful accomplishment of activities in science and engineering learning spaces was tied to establishment of joint collaboration between multilingual students and teachers who engaged in and sustained equitable participation through various forms of communication and coordination.

Sebastian Keller Sebastian Habig

Topic specific differences in supporting organic chemistry learning augmented reality based

Augmented reality seems to be a promising way to get over a representation dilemma during learning organic chemistry and to foster students' understanding. By translating two-dimensional printed illustrations into three-dimensional models, it is supposed that the cognitive load during the learning process can be reduced and so the students can effort a larger amount of working memories capacity for the elaboration of important concepts. However, the question remains open whether the use of Augmented Reality based learning is supportive to the same extent for different subtopics of organic chemistry. Based on research literature paper-based learning materials for three topics of organic chemistry and also an Augmented Reality app were developed, considering design principles of multimedia learning. Especially the learners' learning gains and their perceived cognitive load were investigated in an experimental study. First results indicate that students, who learned with AR-support could achieve larger learning gains, especially for the more complex subtopics, than learners in two reference-groups did, but without an increase in their cognitive load perceptions. It turned out that the way how the Augmented Reality was integrated in the learning setting is a key question of how the learners could benefit from it.

Elizabeth W Kelley

Peer-to-Peer Seminars: Proposal to Use Peers and Structure to Promote Student Learning at Research Seminars

Seminars are a staple of scientific discourse, but little research exists regarding their role and efficacy in promoting student development. The research which does exist suggests that students might not view technical seminars as highly beneficial components of their education. This theoretical paper presents an idea for how science departments could narrow the gap between seminar speakers and student audiences as well as scaffold the development of students as they engage in this professional process.

Angela M. Kelly Monica Bugallo

Cognitive Load, Transfer, and Instructional Decision Making in Middle School STEM Integration

A challenge associated with NGSS implementation is the meaningful integration of science and engineering knowledge and skills in precollege teaching and learning. Instructors in informal settings

have pioneered ways in which engineering design might be adapted for formal science classrooms. This includes interventions designed and taught by university engineers to promote interest in engineering among middle school students. The present study examined instructional decision making in an informal science and engineering camp for middle school students (grades 6-8). This summer program (N=40 students), developed and taught by university faculty, graduate, and undergraduate students in electrical and computer engineering, physics, and science education, was designed to facilitate middle school students' engineering knowledge, design skills, interest, and motivation for learning electrical engineering applications in the context of physical science concepts. The conceptual framework was based upon theories in cognitive load, transfer, and instructional responsiveness. Through the exploratory case study design, three main themes emerged: (1) cognitive challenges related to the abstraction and transfer of engineering concepts and skills; (2) the benefits of collaborative learning; and (3) timing issues with differential rates of task completion. Implications for instructional decision making with regard to cognitive and affective challenges are discussed.

Eleanor Kenimer Gail Richmond

Cultural Historical Activity Theory (CHAT) as a lens for understanding challenges of developing successful formal/informal science education partnerships

In the U.S. recent widespread adoption of the Next Generation Science Standards (NGSS) has required deeper knowledge and different instructional practices from all teachers. The ability to take up NGSS-aligned practices is particularly challenging in under-resourced urban school contexts. Our work has centered on developing sustainable partnerships between teachers and informal science educators (ISErs) to support deeper understanding of how to provide outdoor experiences which are NGSS-aligned and teaching that is specific to their place and the cultural and social needs of their students, making use of several frameworks, including place-based, design-based implementation research, culturally responsive teaching and heads-on, hands-on, hearts-on (3H). In this related paper set, we consider the work ISErs do with other educators, students, and the general public, and how these contribute to their identity (Paper1); evaluate theoretical frameworks as interpretive lenses on such partnerships (Paper2); address how we made use of a virtual environment to establish professional community and "set the stage" for summer and school-year learning (Paper3); investigate the program's impact on teachers questioning and subsequent planning intentions (Paper4); address how specific contextual factors shaped the ways the program was taken up and our leveraging of these factors to support participant learning (Paper5).

Ruth Kermish-Allen Alexandria Brasili

[Program Name]: Powering the Science Learning Process with Co-Created Citizen Science

Citizen science in the classroom has had many benefits including increased environmental stewardship, science content knowledge, graphical interpretation and data literacy, connection to place, and civic engagement, but there has been little studied about how expanded student voice and levels of participation in citizen science projects may influence the science learning process. This study

specifically targets understanding youth learning outcomes related to the scientific process after participation in a co-created variant of citizen science, which originates and grows from start to finish with partnerships between students, teachers, scientists, and members of the public. We developed an innovative tool to capture student understanding of a nonlinear science process. This Science Process Instrument is an interactive and gamified pre-post intervention interview with manipulatives in which students are tasked with describing their approach to a mock science investigation. Using this tool, we found significant increases in students' ability to explain the the science process pre-post which was significantly related to their participation in collaborative activities and communicating about their investigations in and out of the classroom.

Rola Khishfe

Students' Understandings about Nature of Science and Their Argumentation Skills

The purpose of the study was to investigate the relationship between students' understandings about nature of science (NOS) and their argumentation skills, particularly whether informed conceptions of NOS contribute to better argumentation skills. Participants, a total of 125 grade 10 students, responded to an open-ended questionnaire that involved two scenarios addressing socioscientific issues about genetically modified food and water fluoridation. Each of the two scenarios was accompanied by two sets of questions that address argumentation and NOS. A quantitative method approach was used where stepwise regression analyses were performed with three NOS aspects (subjective, tentative, empirical) and argumentation components (argument, counterargument, rebuttal). The results demonstrated positive correlation between argumentation and NOS. For the context of genetically modified food, results showed that the empirical aspect is a significant predictor of all three components of argumentation. Moreover, the results showed that both the tentative and empirical aspects are significant predictors of the argument and counterargument. As for water fluoridation, results showed that the tentative aspect is a significant predictor of argument and that empirical aspect of NOS is a significant predictor of counterargument and rebuttal. Therefore, the study provided evidence illustrating the interconnectedness of argumentation and NOS in relation to socioscientific issues.

Meredith W. Kier

Middle School Teachers and Undergraduate Mentors Collaborating for Culturally Relevant STEM Education

Collaborative partnerships between educators and STEM undergraduate mentors of color pose merit for providing equitable opportunities for all students to participate in STEM. However, the literature is lacking on how these collaborations function to promote culturally relevant STEM education. This qualitative multiple case study investigates how collaborations between middle school teachers and undergraduate mentors promote culturally relevant education in STEM classrooms. We used collaborative coding techniques to analyze the similarities and differences of the overarching phenomenon. We then looked across these codes to identify the main themes in each of the cases,

structured around four cross-cutting categories that included prior experiences and dispositions, shared values, roles assumed in design and implementation, and perceptions of collaboration. We found that teachers and undergraduate mentors implemented engineering design tasks in ways that moved away from traditional teaching approaches to more culturally relevant learning opportunities for students. The partners' STEM identities, how the teacher positioned the mentor in the learners' experience, and the teachers' vision and goals for engineering education influenced the implementation of culturally relevant teaching in the classroom. Implications for designing professional development, drawing on the cultural wealth of undergraduate students of color, and future research will be discussed.

Mijung Kim Qingna Jin

Studies on Visualization in Science Classrooms: A Systematic Literature Review

Visualization has received a growing interest in science education, since the importance of visual representations in students' science learning has been gradually recognized and emphasized by research and practice. To better understand the landscape of research on visualization in science classrooms, we undertook a systematic review to look into what research areas and contexts of visualization science educators and researchers have examined. In particular, this review examined the domains of science subject areas, authors of visualization (teacher, students, or experts), types and purpose of visualization. We focused on empirical research in the last ten years in K to 12 science classrooms. Our systematic search and subsequent screening process yield 48 studies for analysis. The findings suggest (1) research on visualization in science classrooms spans across main science domains, including life sciences, physical sciences, chemistry, earth and space sciences, and socioscientific issues, and grade levels from grade 1 to 12 with variations, (2) the majority of the studies focus on visualization that were developed by students individually, (3) compared with visualization for scientific reasoning and communication, studies focused more on students' concept learning. Based on these findings, suggestions for further research are discussed.

Mijung Kim Janelle McFeetors

Pedagogical Complexity for Engineering Professors: Learning from a Pilot of the SPARK-ENG Professional Learning Program

To enable student-centered and evidence-based pedagogical practices in engineering education, scholars in education in collaboration with engineering colleagues at a large Canadian university created a modular professional learning program for engineering educators called SPARK-ENG (Scholarship of Pedagogy and Application of Research Knowledge in Engineering). Each of the 12 modules in the program include online self-paced readings, activities, videos, and reflections; an opportunity to apply the learning to courses in progress (workplace learning); and a group discussion of the learning experiences (Community of Practice). A pilot study using a program evaluation approach and a situated learning conceptual framework was conducted to evaluate the feasibility and effectiveness of two of the modules in development. Six professors, with varying amounts of teaching experience, completed the modules. Thematic analysis of the Communities of Practice, a focus group discussion, and semi-

structured interviews with the participants revealed that these educators valued the practical over the more theoretical aspects of the modules. Dilemmas with how to use the learning with large and diverse classes emerged. The program developers will use the results of the pilot study to inform the development and implementation of the larger SPARK-ENG program.

Vanessa Kind Helen Cramman

THE IMPACT OF ASSESSMENT CHANGE ON TEACHERS' ORIENTATIONS AND PCK FOR HIGH SCHOOL LABORATORY PRACTICES

This study presents data from a representative sample of 18 high schools in England, obtained via two focus groups in each school, two years apart. The focus groups occurred pre- and post- change in methods of assessment of practical work for 16 and 18 year olds. Data are organised into 'profiles' based on collaborative orientations, drawing on comments relating to aspects of teacher professional knowledge for laboratory work, taken to comprise pedagogical content knowledge (PCK) and science teacher orientations. Schools aligned to four main profiles: Inquiry, Academic Rigor, Process and Activity Driven. Students' experiences of practical work were strongest in Inquiry schools, and weakest in Activity Driven schools. Post-change, fewer schools were Inquiry, and movement towards Academic Rigor was noted. Inquiry teachers were strongest at ensuring their standpoint was retained. These data suggest under-estimation of the impact of in-school teacher collaborative orientations on practices for laboratory work in science, ultimately creating weaknesses and inconsistencies in students' experiences.

Natalie S. King Zachary Collier

Equity and Justice in Engineering and Science: Centering Black and Latinx Culture, Language and Identity

This related paper set is a collaboration of scholars and practitioners from different stages in their careers and explores various methodological, theoretical and pedagogical approaches to move towards justice and equity in science and engineering education. The five papers in this proposal focus on creating opportunities for traditionally marginalized voices to contribute their values and practices towards the creation of knowledge and solutions for all. The set addresses the question of how scholars, practitioners, and community members can work together in bringing the wealth of experiences and practices of students and their lived realities into science and engineering. In alignment with the NARST presidential theme, the presented scholarship addresses "issues of racial inequities and social injustices related to science" and engineering. The ideas presented in these papers call on us to cherish and invite the richness of cultural, cognitive, and linguistic resources that Black and Latinx students bring for engagement and learning in science and engineering while staying true to their communities.

Melanie Kinskey Dana L. Zeidler

Establishing a Community of Practice to Support Elementary Preservice Teachers' Socioscientific Issues-Focused Instruction

The Framework for K-12 Science Education is a United States policy document aimed at improving the quality of science instruction delivered in K-12 schools. A major component of that document is the advocacy for scientifically literate citizens who are capable of engaging in informed decision-making. The socioscientific issues (SSI) approach to teaching provides opportunities for students to develop their scientific literacy skills as they grapple with real world controversial issues. A lack of SSI-based instruction at the elementary level requires structured, formal preparation for preservice teachers to develop their abilities to plan and enact these challenging lessons. In the present study the researchers designed and facilitated a series of community of practice (CoP) meetings to five elementary preservice teachers interested in developing their skills to plan and enact SSI-focused lessons in their student teaching classrooms. Data was collected through a series of recorded and transcribed CoP meetings, lesson plans, teaching observations, and interviews. Findings suggest the CoP approach provided structure and support necessary for these elementary preservice teachers to successfully plan and enact SSI in their classrooms.

Kathryn L. Kirchgasler Cynthia T. Baeza

Language-as-race: Segregated science education and why it matters for efforts to include 'English learners' today

This related paper set draws on raciolinguistic perspectives to raise new questions about racialization, language, and power in science education research, pedagogy, and teacher education. Each paper draws on recent scholarship from Jonathan Rosa and Nelson Flores to shift the gaze from the linguistic practices of racialized speakers (e.g., are minoritized students acquiring 'scientific language'?) onto the professionalized practices of the listening subject (e.g., how are teachers expected to arbitrate who is speaking or writing 'like a scientist'?). The first three papers turn scrutiny onto prevailing modes of perception in U.S. science education. Through analysis of science teacher surveys, language expectations in science course materials, and pre-service teacher interviews and small group discussions, these papers illustrate exclusionary processes of linguistic authentication, racializing appraisals of disciplinary legibility, and the typologizing of who is identified/identifiable as 'talking science.' The fourth paper situates these patterns in historical perspective by examining how similar raciolinguistic distinctions took shape in the segregated science instruction offered to Mexican American students a century prior. Together, the papers interrogate foundational assumptions shaping the White-perceived listening subject of U.S. science education to open a more robust dialogue concerning linguistic and racial justice in the field.

Eric A Kirk Troy Sadler

Assessing Socio-scientific Systems Thinking for the COVID-19 Pandemic

This paper outlines the development and testing of a multiple-choice socio-scientific systems-thinking assessment using the COVID-19 pandemic as context. We begin this paper with an overview of socio-scientific issues, socio-scientific modeling, and systems thinking. Next, we discuss the theoretical framework used to design this assessment as well as the rationale used in the design process. We follow this with a discussion of data collected using this assessment from 34 public high school students in the Midwest United States. Overall, this assessment showed good internal consistency with a Cronbach's Alpha of 0.85. The mean score was 13.52/19 with a standard deviation of 4.10. Item difficulty of most items fell between 0.91 and 0.48. A novel metric, the functional structure index, appears to be predictive of item difficulty (r2 = 0. 724, p < 0.000), although there are limitations to this claim. We conclude this paper with a discussion of the significance of this work as it pertains to the theme of this conference: unity and inclusion for global scientific literacy.

Vance J. Kite Soonhye Park

The Power of Context: Factors that Influence Teachers' Implementation of Unplugged CT-Infused Science Lessons

There is growing recognition that the problem-solving practices that comprise computational thinking (CT) are a fundamental component of Twenty-first Century life and work. Historically, opportunities to learn CT have been confined to computer science (CS) courses that lack diversity. To combat this inequity, scholars have proposed integrating CT practices into core curriculum – especially science, technology, engineering, and math (STEM) curriculum. However, successful CT infusion depends on frameworks to guide integration, professional development for teachers, and resources to support their efforts. Research pertaining to each of these areas is nascent. This study addresses these needs through a collective case study of ten secondary science teachers' implementations of a novel, process-based, unplugged approach to CT/science integration and the factors that supported and hindered their efforts. The results of this work reveal that (1) an unplugged and process-based approach to CT/science integrating CT in science classrooms, and (2) educators' teaching context (e.g., Administration, Colleagues, Curriculum) exerts a strong influence on their CT-integration efforts and persistence. These findings point to the need for further research on unplugged CT/science integration of CT integration at the school, district, and state levels.

Matthew Kloser Michael Szopiak

Effects of pedagogical interruptions on secondary student interest, engagement, and comprehension of narrative science videos.

Narratives have significant potential as a learning tool in secondary science classrooms. Both empirically and conceptually, the narrative genre supports student comprehension because it reduces the amount of prior knowledge needed and creates higher attention allocation through increased interest and structure recognition. This experimental study compares the impact of pedagogical interruptions – embedded questions – versus no interruptions on high school biology outcomes of interest, engagement, and comprehension when students are watching a narrative science video. One hundred

seventy-one high school biology students of varied levels watched a narrative science video and completed interest, engagement, and comprehension questions in one of four randomized conditions: 1) answering no associated questions, 2) answering priming questions before watching; 3) answering questions throughout the video; or 4) answering questions after the video. No difference existed between conditions for engagement, interest or direct recall; however, students in condition 3 answered global comprehension level questions more accurately, regardless of whether they were introductory or advanced students, a difference which was also maintained one week later. Given the increased use of video in science classrooms, these findings provide causal evidence for embedding questions throughout viewing experiences as interest is maintained and global comprehension is increased.

Yeonjoo Ko Hyunju Lee

ENACT Project: Promoting Pre-service Science Teachers' Perceptions on Social Responsibility of Scientists and Engineers

There have been efforts to design and implement educational programs which let students examine the complexity of SSIs and take responsible action based on student-led research findings. Sharing the perspective above, we designed an ENACT program that emphasizes both critical examination of SSIs and responsible action to promote a sustainable society and environment. The current study implemented the ENACT program to 32 pre-service science teachers (PSTs) over a semester and investigated the effects of the program. We collected data by administering the scales including Views on Social responsibility of Scientists and Engineers (VSRoSE), understanding of SSIs, and SSI teaching. Paired-samples t-tests were conducted to compare the scores between the pre- and post-tests. In addition, focus group interviews were conducted to explore their experiences of ENACT projects, and all were transcribed for analysis. Results indicated that PSTs significantly improved their perceptions of the social responsibility of STEM professionals; specifically, their beliefs about STEM professionals having a responsibility to participate in various societal practices. In addition, they improved their understanding of SSI as well as their teaching efficacy toward SSI. We believe this study will have pedagogical implications to support PSTs and in-service teachers for cultivating socially responsible citizens.

Karel Kok Burkhard Priemer

Certain about uncertainty: quality of students' justifications in comparing data sets

Measurement uncertainties are an essential part of a measurement result. The topic is, however, rarely addressed in the high school physics classroom and students struggle a lot with variance in data sets. We have developed and tested a sequential Digital Learning Environment (DLE) on the topic of measurement uncertainties. In our study with 154 participants of grades 8 through 11 in Germany, we have tested the DLE using a pre-post design. The pre- and post-test consist of a data comparison problem where participants compare a data set, make a decision, and justify this. These justifications are coded based on which quantity is compared and what the deciding criterion is, indicating the quality

of the justification. Results show that with increased teaching through the DLE, there is a dramatic increase in the quality of participants' justifications. Also, we find this to be independent of grade level.

Tormi Kotkas Jack B. Holbrook

Intervention Highlights the Importance of Career Awareness Promotion on Students' Equal STEM Career Awareness Development

Estonian middle school students have shown great competence in science in recent PISA tests. However, similarly to other countries only the minority of students aspire to STEM careers and there are large gender differences in aspired STEM fields. Several studies conducted in Estonia imply that students and teachers lack awareness of STEM careers, which might be one of the reasons why only a minority of students pursue a STEM career path and why there are gender differences in students' career aspirations. This paper examines the impact of a longitudinal STEM career awareness promoting intervention on middle school students' (aged 13-15 years old) STEM career awareness. This study implements quasi-experimental pretest—posttest design with non-equivalent experimental and control groups and uses concept mapping technique for determining students' STEM career awareness promoting teaching and learning modules helped to support both boys' and girls' STEM career awareness, whereas among control group only girls' STEM career awareness grew. These results imply that it is important to support students' STEM career awareness development in science lessons to provide students with equal opportunities for making well-informed decisions either toward or away from STEM careers.

Rebecca Kotler Maria Varelas

Science Learning, Theatre, and Practices of Respect: Generative Engagement through Embodying Science in Urban Elementary Classrooms

Performing arts may provide unique ways of bringing relationships, power sharing, emotions, closeness, safe spaces for risk-taking in idea generation, and ample opportunities for reflexive practices to the science class. Informed by drama and movement practices, relational pedagogy and practices of respect, and sociocultural and critical perspectives for liberatory education, we explored ways in which students of color in elementary and middle school grades made sense of science ideas and constructed identities through embodying science with gestures and whole-body movements with the support and encouragement of teachers and teaching artists in the context of a partnership of school- and university-based educators. Ethnographic methods, which included a variety of data sources along with movement analysis and thick description of science embodiments led to three findings: Children's embodiments offered them opportunities to both represent science ideas and sense them in their bodies via the intensity and energy of their movements; Communal learning was afforded by the embodiment of science ideas; Emotions were enmeshed in children's embodied science storytelling. These findings compel science educators to consider the affordances of involving students' whole bodies in exploring and learning science through embodied performances inside and outside classroom spaces.
Joseph S. Krajcik Samuel Severance

Project-based Learning Contexts for Developing Adaptation Design Principles that Promote Engagement and Equity

Adaptation design principles that teachers use for enhancing student learning How can teacher professional learning be designed to promote teacher agency and responsive teaching? The goals for professional learning are multifaceted due to complex demands placed on teachers. While enacting curriculum, a teacher must be equipped to engage students productively. They must improvise teaching to support science practices and build on student experiences and current understanding, create equitable and culturally relevant contexts, and support social and emotional learning. This team of researchers from three universities presents a set of disparate but consequential design principles centered on supporting teachers to adapt curriculum according to context, focused on different teachers and grade levels, but all enacting Project-based Learning. An adaptation design principle is an actionable, evidence-based claim that teachers employ to navigate adaptations so teaching sustains the deeply rooted foundations of productive and responsive science teaching. Paper 1 explains the process for using adaptation design principles to frame Professional Learning. Paper 2 describes design principles for creating equity-centered environments, paper 3 is centered on the design principles that support engagement in developing, using and presenting models, paper 4 shows how adaptation design principles can be used in Professional Learning to leverage adaptations based on culturally responsive teaching.

Robert Krakehl Martin Francis Palermo

Intersectional Analysis of Advanced Placement Chemistry Enrollment and Performance

Research has shown that student access and achievement in advanced precollege chemistry has been largely inequitable when considering the demographic factors of ethnicity and gender. In this non-experimental observational study, an intersectional analysis of ethnicity and gender was utilized to examine student access and achievement in AP Chemistry during the 2019 examination administration. Results indicated that access to AP chemistry was equitable across gender, with slightly higher enrollment for women compared to men, but large disparities existed between ethnic and intersectional groups in terms of access and performance. Ethnic groups traditionally underrepresented in STEM continue to be underrepresented in AP Chemistry participation. Although more women took the AP chemistry exam than men, they had higher failure rates. Women of color had the highest failure rate, indicating potential problems with prior academic preparation, stereotype threat, and access to curricular resources and high quality teaching. These results suggest widescale interventions are necessary to improve chemistry knowledge and skills and reduce the achievement gap in AP chemistry performance. Implications for policy and practice are discussed.

Sarah Krejci Hector N Torres

Utilizing argument-driven inquiry with scaffolding to improve socioscientific argumentation in undergraduate students

The socioscientific argumentation intervention utilized an argument-driven inquiry model with scaffolding modified from Hasnunidah et al. (2015) in which students participated in three stages of learning (1) initiation (2) development (3) reinforcement. In the initiation stage, students are provided with online coursework on Argument diagramming created by the Online Learning Consortium (OLI) which introduced students to sensemaking and articulation strategies and measured students' metacognitive activities during the lesson. In the development stage, students are provided with readings and videos on the health benefits, social impacts, and climate change impacts of Genetically Modified Foods (GMOs) and Organic Food. In the reinforcement stage, students participated in a blind taste test of GMO and Organic Foods. In both the development and reinforcement stage, students worked in small groups using the argument diagraming skills from the OLI lesson to collect and analyze evidence from the readings and activities, produce a tentative argument, participate in class inquiry and reflective discussions, and complete an individual written summary of the class's argument, evidence, and conclusion.

Rishi Krishnamoorthy Edna Tan

Reimagining Virtual Participatory Design Research: Supporting Youth's Rightful Presence in a Community Science Project

The COVID-19 pandemic caused schooling across the globe to pivot to virtual learning environments such that online learning has become 'the new normal'. Education researchers, similarly, were advised to pivot towards and adapt to virtual platforms. Considering the trade-offs that different kinds of research approaches might encounter during such a pivot is especially pertinent for community-engaged research projects. The larger project in which this study is situated engaged historically minoritized middle school youth, school teachers, and university researchers in co-designing a 7th grade biology curriculum centered on a community-identified health concern through virtual design-team meetings. Unlike in-person participatory design, the virtual environment presents novel challenges and opportunities for youth to make choices about their participation. We ask: How do youth participate in a virtual biology curriculum design-team environment focused on exploring community-based health issues? In what ways did the adults' framing of youths' participation support and/or hinder their rightful presence in the virtual design meeting space and with what consequences for knowledge creation? Taking seriously youths' acts of non-participation as moments of resistance, this paper illustrates how educators can restructure virtual spaces and collaboratively work towards youths' rightful presence in the participatory design team.

Harini Krishnan Lama Jaber

Make or Break Collaborative Disciplinary Engagement in Science: Managing Conceptual Uncertainty in Group Work

While conceptual uncertainties position students to engage in the disciplinary practices of science in meaningful ways, that engagement is dependent on how students respond to and manage such uncertainties. The current study examines various epistemological, social, and affective dynamics and how they influence the management of conceptual uncertainties in one group of middle school students in a science classroom. Using multimodal discourse analysis, we found that students' persistence in disciplinary engagement is not only dependent on the presence and recognition of conceptual uncertainties but also on how students take up and manage challenges along epistemological, social, and affective dimensions. Our work can inform educators interested in supporting students to navigate the complex and multidimensional dynamics of collaborative sensemaking in service of promoting disciplinary engagement in science.

Stina Krist Nitasha Mathayas

Teacher noticing for epistemic agency: What cues teachers to open up space for student sensemaking?

Participating in science practices requires that students take intellectual ownership in developing explanatory science ideas. We refer to students' roles in making those decisions as epistemic agency. Supporting students' epistemic agency is pedagogically challenging in that it requires teachers to notice, interpret, and respond to an even greater range of classroom instances than those related to responsive teaching, all in real time and with a great deal of uncertainty and variation. This paper extends a framework for teacher noticing developed in mathematics education to characterize the noticing practices of two experienced teachers who both expressed commitments to supporting students' epistemic agency. We identified three categories of pedagogical phenomena that they noticed: (1) student ideas; (2) student participation; and (3) curricular enactment. We also characterized five types of responses to those phenomena that varied along two dimensions: whether the response was active vs. passive, and whether their intent in responding was to expand or diminish space for the observed phenomenon. These findings are important additions to a noticing framework for epistemic agency and contribute to the development of tools that can support both research and practice around supporting students' epistemic agency in science learning.

Jerrid W. Kruse Isaiah Kent-Schneider

Learning to Teach NOS: How do NOS instructional views develop during semester-long NOS course?

While much is known about teacher learning of nature of science (NOS) concepts, less is known about how teachers develop an understanding of how to effectively teach NOS. Therefore, this study investigated the NOS instructional views of preservice secondary science teachers as they completed a semester-long NOS course. At four times during the semester, data was collected through written artifacts and interviews about NOS instructional views. Participant NOS instructional views generally followed the following trajectory: (1) teaching misconceptions, (2) inclusion of accurate implicit messages, (3) mimicking of course activities using explicit-reflective instruction, and (4) creation of new activities using explicit-reflective instruction. Participants moved from NOS as a topic to a more embedded approach to NOS instruction and their questioning moved from general NOS to more specific NOS aspects. Other findings include that preservice teachers tended to use more abstract and contextualized activities for the outer rings of the Family-resemblance Approach to NOS. Features of the NOS course may account for some aspects of the learning progressions observed.

Marcus Kubsch David L. Fortus

The interplay between students' motivational profiles and science learning

Students' motivation plays an important role in successful science learning. However, theories of motivation propose that students' motivation is composed of multiple factors that interact in complex ways and influence metacognitive processes such as self-evaluation. This complexity is further increased because students' motivation and achievement influence each other over time. It is challenging to study the co-development of motivation and learning due to these complex interactions which can vary widely across individuals. Person-centered approaches that capture students' motivational profiles can help to better understand the complex interplay between the co-development of students' motivation and learning. We employed a person-centered approach in order to study how the motivational profiles of N = 426 middle school students developed over the course of a 10-week energy unit and how that development was related to students' learning. We identified four characteristic motivational profiles with varying temporal stability and found that students' learning over the course of the unit was best characterized by considering the type of students' motivational profiles and the transitions that occurred between them. We discuss implications for the design and implementation of interventions and future research into motivation and learning.

Richard Lamb Knut Neumann

Exploring Science Student Learning Outcomes using Machine Learning Classifications During Online Sessions

Automated interactive learning management systems and the associated online video-based learning environments are thought to increase learning outcomes related to science content and practices. The purpose of this study is to examine how hemodynamic response data may be used to develop student level answer predictions via machine learning algorithms as students engage with an online learning management system in a science classroom. Forty participants (n=40), 21 females, and 19 males were recruited from a charter school located in the north eastern United States. Students watched a recorded video consisting of a 20-minute lesson and explanation of the process of DNA replication. During instruction, a female instructor on a computer screen provided an explanation of the process of DNA replications to the students is predictive of student correct and incorrect responses on the questions presented about the content. With error rates in the predictive models below 30%, results suggest that hemodynamic response can assess levels of student involvement in video-based tasks. This may lead to development of novel approaches in the use of visual media for learning, allowing science educators to evaluate whether students can assimilate content using hemodynamic data.

Elon Langbeheim Edit M. Yerushalmi

The motivational consequence of pattern-seeking fatigue

Scientific investigations encompass two forms of activities – seeking patterns and regularities in phenomena, and explaining them using mechanistic models. In a recent study, Tang, Elby & Hammer, (2020) argued that middle school teachers tend to direct their instruction towards pattern seeking, and avoid meaningful mechanistic discussions. This tendency, they argue, is rooted in curricular standards and policy documents that emphasize pattern seeking, especially with younger learners. In our suggested presentation, we extend the discussion on the prevalence of pattern seeking over mechanistic reasoning to include motivational factors. Our study is based on feedback from teachers who implemented a novel inquiry-based learning unit on oscillations in 9th grade, and our own observations of their classrooms. The unit was designed to fulfil the local requirement of inquiry-based learning in which students formulate research questions and conduct investigations. We summarize the teachers' impressions of their students' sources of motivation and interest. Both teachers reported that their students were highly engaged during the experimental phase of the learning unit, but less engaged in the mechanistic/theory phase of the unit. We conclude by suggesting directions to relate teachers' backgrounds and their students' motivations in classroom investigations.

Jeppe Langkjær Bjørn Friis Johannsen

The Paradox of Dedication: Agonistic interviews on preservice science teacher students' choice-narratives

This study uses agonistic interviews, an actively confronting interview style, to understand students' choice-narratives in relation to not applying for a preservice science teacher honors program. The study departs from the common experience that well-meaning STEM initiatives suffer from waning interest on the part of the target group. In this case the initiative is well-funded and should in theory attract applicants, if for nothing else, because enrollment comes with a monthly stipend and no risk to the student. We interview five students who are the kind of student the program aims at, to try and convince them to apply. Analysis of the conversation allows us to distill three themes, 'Not talents?', 'The paradox of dedication' and 'A question of time'. That is: students do not identify as talented, the program requires dedication, which they cannot promise, and given sufficient time and effort the choice-narrative can change. We suggest, however, that giving this time and effort will lead the interviewer to new understandings. Rather than change students' minds, they might change their own mind. Thus, we suggest agonistic interviewing as a development tool for STEM initiatives that aim to be relevant to the students they cater for.

Axel Langner Nicole Graulich

Teaching digital multimedia design with eye-tracking – exploring a new teaching approach for student teachers

As digitalization advances, learning processes can be supported in many ways. The expectation that student teachers learn to design, choose, and use appropriate digital multimedia in teaching increase likewise. A university course should ideally develop student teachers' attitude, subjective norm expectation, and self-efficacy which are described as influencing their motivation towards future digital media use in teaching. A crucial aspect, however, when using digital media for learning purposes is to know how learners perceive and learn with them. Assessing perceptual processes in multimedia learning with eye-tracking can serve as a mean to support student teachers in evaluating learners' perception and cognitive processes. This might initiate a meaningful reflection about multimedia design and could positively influence student teachers' attitude, subjective norm expectations, self-efficacy, and motivation. For this purpose, a new course design was explored with a small group of student teachers, in which they 1. created digital media respecting design principles, 2. investigated learning processes in small empirical eye-tracking studies, and 3. reflected about purposeful design of teaching material. Aim of this explorative study was to investigate to what extend this course design influences student teachers' motivation to use digital media in future teaching and their understanding about multimedia design.

Daniel Laumann Julia Welberg

Influence of Digital Learning Design Features and Self-Regulation on Students' Behavioral and Emotional Engagement

Learner engagement is key for teaching basic scientific literacy. While learners' emotional engagement is a consequence of their situational interest, cognitive engagement is a result of learners' self-regulation and behavioral engagement expressed by the processing of instructional tasks. For the development of learning materials, it is important to positively influence situational interest, self-regulation, and task processing to expect positive influences on the engagement in consequence. In this sense, the present study seeks to investigate design features of digital learning environments to positively influence students' situational interest, self-regulation, and formal task performance as an important basis for students' emotional, cognitive, and behavioral engagement and, therefore, support the acquisition of scientific literacy as well as getting learners to choose science courses. The results show that students seem to be interested in educational videos, but experiments may hinder students processing of task learning with digital materials. The results also support previous work on the importance of contexts for physics education and can guide rather intuitively guided development processes of digital instructional materials by corresponding research findings in the future.

Daniel Laumann Malte Ubben

Mobile Learning in the Physics Classroom – Should Students Bring or Schools Provide Smartphones?

Digital technologies influence almost every area of life – naturally also education. Among these devices, smartphones can be seen as the "swiss army knife" of education in the physics classroom. Smartphones have great potential, for example, for measurements and simulations, but the question arises which smartphones should be used. Students could use their own smartphones in classroom ("bring your own

device" - BYOD) or students could be given mobile devices in class (POOL). In the POOL approach, less distraction and better surveillance can be expected compared to the BYOD approach. Existing studies paint a heterogeneous picture regarding the advantageousness of one or the other approach. The present study follows a quasi-experimental comparison group design (BYOD vs. POOL; N = 201) and analyzes the influence of both approaches on students' learning performance, motivation, and concentration. The results of the present study show that when comparing the use of smartphones in physics classes according to the BYOD and POOL approaches, perhaps surprisingly, almost no differences can be found. There seems even to be a tendency for a rather small advantages of the BYOD approach over POOL that can be found for all data.

Thanh K. Le Regina Barber DeGraaff

Cultivating and supporting STEM faculty allyship

Because experiences inside and outside of the classroom impact collect students' achievement and persistence in STEM, cultivating STEM faculty allies to advocate and advice equity, inclusion, and diversity (EID) at their institutions is critical. Faculty have potential to reduce demographic disparities in interest, persistence, and employment in STEM fields and promote change in STEM culture to reduce instances of sexual/racial harassment and microaggressions. In this study, we interviewed four tenure-track faculty members at the beginning and end of the academic year. Participants were part of a college-wide EID program designed to support faculty engaged in EID action through three goals: to build a community around faculty EID action, to facilitate more informed allyship, and to create more transparency and accessibility of available resources. We present multiple case studies to describe how faculty enact allyship. In particular, we focus on one element of effective allyship: faculty self-reflection on how their identities influence and impact their EID actions. This is important because self-reflection and interrogation of the role of privilege and power in one's own experiences and actions can help mitigate the reproduction of inequities.

Judith S. Lederman Selina L. Bartels

International Collaborative Investigation of Third Grade Students' Understandings of Scientific Inquiry

The intent of this collaborative interntional project is to report on grade three students' understandings of SI across the globe. This study rounds out the two previous studies conducted on what grade seven and grade twelve students know about scientific inquiry. This symposium will bring in researchers from around the globe to discuss their findings on primay school students' knowledge about NOSI and how it translates through middle and high school. This large scale international study has impact on scientific literacy globally.

Dennis M. Lee Brian M. Donovan

A Case for Humane Genetics Education: How Students Used Genetics Knowledge to Argue About a Racial Disparity

The genetic essentialist belief that racial groups have different genetic essences that determine their physique, cognition, and behavior can be influenced by genetics education. Recent research has shown that at the classroom level, curricular interventions that teach students complex forms of genetics knowledge can, on average, reduce their belief in genetic essentialism. However, few have investigated how students argue for or critique arguments that explain a racial disparity. We analyzed the arguments that students made in focus groups to explain racial disparities in player representation in the National Football League. In particular, we focused our analysis on two participants, LaVar and Lemon, who exchanged arguments and critiques about each of their claims. We found that the intervention succeeded in breaking down LaVar's essentialist belief that genes alone determined human traits but was unsuccessful in changing his belief that genes are the most proximate cause for human traits. We also found that Lemon had difficulty critiquing LaVar's claims effectively. These results suggest that conceptual change of essentialist beliefs is not always coherent, and that more robust instruction on argumentation is needed to help students use genetics content knowledge to refute genetic essentialist claims.

Gyeong-Geon Lee Hun-Gi Hong

Automated Assessment of Students' Response to Free-response Items on Particulate Nature of Matter Utilizing AI

This study developed and validated an automatic assessment tool that both considers students' drawing and writing representations using machine learning (ML). The data was collected from 1,028 2nd–11th graders from South Korea, using the Test About Particles in a Gas questionnaire (Novick & Nussbaum, 1981). Students' pencil-and-paper free-responses were coded with respect to two dimensions - structural (particulate/continuous/others) and distributional (expanded/concentrated/others). After reaching a consensus on the coded responses, ML models were trained to assess students' drawings and writings on PNM. For students' drawing, a pre-trained Inception-v3 model was used to pre-process the data, followed by Support Vector Machine used for classification. Students' written responses were tokenized, and a dictionary that includes the scores for scientific semantics was made. The final model for overall assessment of both drawing and writing yielded high Machine-Human Agreement performance (kappa = 0.800–0.881, accuracy = 0.859–0.956, precision = 0.865–0.957, recall = 0.859–0.956, F1 = 0.859–0.956, and AUC = 0.944–0.995), which varied by the ML algorithm. There were some variances in the ML model performances according to the school level. This study shows the possibility that artificial intelligence technology can be used to implement a learning analytics system that assesses students' representations of scientific concepts, particularly visual ones.

Hyunju Lee Yuhyun Choi

Exploring the Perception of College Students in STEM Fields on Social Responsibility of Scientists and Engineers

As the rapid development of science and technology continue to raise social and ethical issues, the importance of cultivating social responsibility of scientists and engineers has been more emphasized. Despite this growing importance, well-designed programs for enhancing the social responsibility of STEM college students are rarely found. Thus, in this study, we aimed to examine the perception of social responsibility of college students in STEM fields as an initial step for promoting social responsibility of scientists and engineers) and reported their background information. Descriptive statistics were conducted as well as independent-samples t-test and ANOVA were conducted to compare the VSRoSE scores by gender, major, and school years. Ward's clustering analysis was also conducted to classify students on their perceptions of social responsibility. Findings indicated that students' overall scores were high in all factors, and they showed relatively higher scores in the first three components than the others. In addition, a cluster analysis detected five distinct social responsibility types among STEM college students. This understanding will serve as a basis for designing education and support for future STEM professionals to enhance social responsibilities.

May Lee Michael Bennett

Relating TAs' Enacted Instruction to their Beliefs about Teaching and Learning in an Introductory Physics Tutorial using CHAT

Teaching assistants (TAs) can greatly influence the quality of undergraduate physics education because they often provide more individualized attention to students during tutorials than course instructors during lectures. Instruction is informed by beliefs about teaching and learning, yet little is known about the relations between TAs' instruction and those beliefs. To investigate these relations, we used cultural historical activity theory (CHAT) to investigate how the rules (tutorial norms), tools (resources), and divisions of labor (roles) perceived by TAs within their tutorials relate to the outcomes (enacted instruction). By adopting a qualitative case study design, we collected data through individual interviews with three TAs, field notes and video-recordings of their tutorials. The analysis showed that while TAs perceived the same rules, they differed with respect to the tools and divisions of labor; these differences relate to different observed modes of instruction. These findings will inform the design of professional development for TAs in undergraduate physics.

Okhee Lee Todd Campbell

Justice-Centered STEM Education to Address Pressing Societal Challenges Using the Case of the COVID-19 Pandemic

COVID-19 has impacted nearly every aspect of life in the US and across the globe. This pandemic presents an example of why scientific literacy, conceptualized broadly to include science concepts, the nature of scientific evidence, and ideas about how science works, is so critical. We contend that it is

essential for the spaces of science teaching and learning to be spaces in which complex issues like the COVID pandemic are explored. We contend that the science education community has a key role to play in supporting expanding dialogues and learning about critical societal issues particularly those, like the COVID crisis, which are so critically connected with science. This paper set features work from five research teams which took up the challenge of responding to the pandemic through science education. The researchers come together here to share some of the ways in which science education has been leveraged in the midst of the COVID crisis. The goal of the session is to surface what the science education community has learned through the current crisis, critical research directions that are needed, and how the community can position itself for effectively responding to the next global crisis that will inevitably emerge.

Samuel Lee Kevin Cherbow

Multimodal revoicing: Embodied student resources to support students' explanations of science phenomena

Exploring phenomena and engaging in the practices of science is where students figure out science instead of memorizing about it. This shift produces an opportunity for teachers and researchers to attend to what students say and do when figuring out science, especially for historically language minoritized students. Although there are plenty of examples of research of what students say, there is a lack of what students also do (i.e. gestures) in sensemaking discussions when figuring out phenomena. Therefore, we investigated: (1) what are the embodied resources (i.e. gestures) used when students explain phenomena? (2) how do these embodied resources support students' explanations of science phenomena? This study used conversation analysis of video transcripts and images to see how middle school students used their language and gestures to support their figuring out scientific phenomena. Our findings propose that gestures support students' language searches within their semantic work and that student embodied actions (i.e. gestures) can be multimodally revoiced to represent scientific sensemaking to explain a phenomenon. This study contributes to noticing student thinking as more than a language-centered and monolingual view but to also see the multimodal resources language minoritized students bring into the classroom.

Sarah Jaewon Lee Ashlyn Pierson

Elementary Science Teachers' Use of Representations to

Central to equity-focused reforms in science and engineering education is the need to expand what is valued in disciplinary learning, desettling taken-for-granted norms about what counts as valuable ways of knowing, reasoning, and communicating. Creating more expansive spaces for learning science and engineering supports learners to see more of themselves in these disciplines, to bridge their families' and communities' cultural practices and experiences to their disciplinary work, and to disrupt powered racialized and gendered hierarchies in schools. This related paper set examines the contexts of teachers' learning to develop more expansive learning environments in science and engineering. Looking across pre-service and in-service teacher learning communities, this symposium will consider different designs

for fostering teachers' learning; explore different lenses for examining how teachers support expansiveness in science and engineering; and investigate the tensions teachers experience as they challenge culturally dominant frames of teaching and learning science. These papers aim to contribute to ongoing conversations about broader sociopolitical contexts of expanding what is valued in science and engineering, taking a teacher-focused lens to understanding how to achieve more equitable spaces for learning these disciplines.

Tammy D. Lee Carrie Lee

Virtual Rehearsal Simulations as Authentic Practice Spaces for Developing Scientific Discourse Skills

Learning science involves communicating ideas, observations, and findings. Science educators use peer to peer (PTP) groups for practicing teaching. This study uses practice sessions called rehearsals designed as specific teaching episodes focusing on elementary teacher candidates' (ETC) development of scientific discourse skills. This NSF work explored the use of traditional PTP rehearsals on ETCs discourse development compared to using an innovative technology environment called Mursion® (TeachLivE[™]), a virtual rehearsal simulation (VRS). Results show ETCs increased in their use of discourse moves in both contexts. The VRS group used discourse that focused on students' ideas and understanding more frequently than the PTP group. This study explores using innovative technologies for creating valuable teaching experiences.

Louise Lehane

Using a PCK lens to capture pre-service science teachers' internalized knowledge of Nature of Science

This study is situated within an initial teacher education provider in Ireland. The aim was to use a pedagogical content knowledge (PCK) tool to capture pre-service science teachers' knowledge of Nature of Science (NOS). NOS is now an explicit focus in the post-primary curriculum in Ireland and is therefore critical that our pre-service teachers can recognise NOS within their own and their students' practices. The tool, known as content representations (CoRe), was developed initially to capture teacher PCK. It has since been used to serve different needs of researchers (Lehane, 2016). This study analyses CoRes that were developed by pre-service teachers (n=12), working within a professional learning community, using the Family Resemblance Approach (Erduran & Dagher, 2014) to NOS as its framework. The main findings show that while they held particularly surface understandings of science as a social-institutional system, they did demonstrate understanding of science as a cognitive system with consideration for scientific practices. Their knowledge of NOS overall was lacking. This study discusses NOS as part of a teacher's PCK and uses a PCK tool to capture such understandings and provides an amended CoRe design to facilitate future NOS knowledge development.

Catherine Lemmi

Language ideologies in science course materials

This related paper set draws on raciolinguistic perspectives to raise new questions about racialization, language, and power in science education research, pedagogy, and teacher education. Each paper draws on recent scholarship from Jonathan Rosa and Nelson Flores to shift the gaze from the linguistic practices of racialized speakers (e.g., are minoritized students acquiring 'scientific language'?) onto the professionalized practices of the listening subject (e.g., how are teachers expected to arbitrate who is speaking or writing 'like a scientist'?). The first three papers turn scrutiny onto prevailing modes of perception in U.S. science education. Through analysis of science teacher surveys, language expectations in science course materials, and pre-service teacher interviews and small group discussions, these papers illustrate exclusionary processes of linguistic authentication, racializing appraisals of disciplinary legibility, and the typologizing of who is identified/identifiable as 'talking science.' The fourth paper situates these patterns in historical perspective by examining how similar raciolinguistic distinctions took shape in the segregated science instruction offered to Mexican American students a century prior. Together, the papers interrogate foundational assumptions shaping the White-perceived listening subject of U.S. science education to open a more robust dialogue concerning linguistic and racial justice in the field.

Stefanie Lenzer Marvin Roski

Towards an Inclusion of All in Lab Courses – The Case of a Blind Student

A scientific literacy is a basis to address many 21 century challenges. Accordingly, developing scientific literacy for all members of our society is one of the central goals of modern science education. Toaccomplish this goal, science education needs to address both the concept of scientific literacy and the needs of all students. A few studies report working with blind or visually impaired students in university chemistry courses and demonstrate how these students can be enabled to carry out different tasks. However, no framework has been presented yet that supports lecturers to design/redesign university chemistry courses that enable participation for all. To address this issue, we present a study of applying a newly developed framework striving for scientific literacy for all. Based on the case of a blind biochemistry student, we show for the first time how lecturers can use the framework to acknowledge diversity, identify barriers, and enable participation in a university chemistry lab course.

Susan Letourneau David Wells

Engaging children and caregivers in engineering design projects: Development of maker workshops and digital tools

Research within the maker movement has shown the value of hands-on making for supporting many aspects of STEM learning, especially skills relevant to engineering and design. Decades of research also demonstrates that children's interactions with caregivers are a critical avenue for informal STEM learning. However, more evidence is needed to understand how maker programs can be designed and facilitated to support children and caregivers in engaging in the engineering design process together. In

this design-based research project, a team of maker space educators, researchers, and media developers worked together to iteratively develop and refine a toolkit of resources to introduce children ages 8-11 and their caregivers to the engineering design process. Resources included a series of inperson workshops in a museum-based maker space, and an accompanying app that families used to guide them in planning and creating a prototype of their own design ideas. Through the development and testing of these resources, we identified strategies that were effective in supporting children's use of specific engineering design practices, caregivers' involvement in children's learning, and caregivers' self-reported confidence in and likelihood of engaging in similar projects with their children at home.

Kathryn Leve Ute Harms

Climate Literacy: What do teachers need to know? - A Delphi Study

Several studies show that students often lack conceptual knowledge and show multiple misconceptions when explaining climate change (Boyes & Stanisstreet, 1993; Flener-Lovitt, 2014; Shepardson et al., 2011). Hence, it is often argued that science education should focus on conveying sufficient conceptual knowledge about climate change, its causes, consequences, and potential ways of adaptation and mitigation. However, besides scientific content knowledge, decision-making and the intention to act in a climate-friendly manner seem also to be influenced by non-scientific factors such as attitudes and value attribution (Dietz, Dan, & Shwom, 2007). The USGCRP (2009) thus promotes to focus education on climate literacy, which includes specific knowledge about climate change, as well as skills and attitudes relevant to the topic. So far, studies examining the impact of climate literacy on actual decision-making are scarce, and the general picture about other factors that contribute to young learners' conceptions of climate change – including the media, family, peers, but also emotional attachment and risk perception – remains somewhat unclear. In this related paper set, we aim to elaborate how climate literacy can be modelled and assessed, how it can be promoted through meaningful instruction, and how teacher professional development can contribute to this.

Keren Sarah Levy Keren Mintz

Citizen Science in School: the Case of the Invasion of Wild Boars

Taking citizen science to school may contribute to multiple stakeholders, including the educational community by promoting science learning. The current research focused on an ecological, policy-driven school CS project addressing a wicked problem: the invasion of wild boars to a large city in Israel. In the project, nine-grade students processed and analyzed a large number of photos from trap cameras placed on the wild boars' trails. Learning objectives were a) learning in the context of a wicked scientific and policy problem, and b) engaging students in inquiry-based learning and using scientific practices. The research aimed to explore how the different adult stakeholders view the project: its goals, implementation, and outcomes, and how do the students view its outcomes. Data included: interviews with the adult stakeholders and open-ended questionnaires for students. We found that students were engaged in inquiry learning and developed scientific practices and content knowledge. However, socio-environmental outcomes were not identified. Additionally, a gap was revealed regarding the

stakeholders' perceptions. We argue that socio-environmental aspects should be explicitly addressed in CS designed for learning. Findings also highlight the importance of a meaningful conversation between stakeholders when initiating and designing CS project.

Marissa A. Levy Amanda Peel

Co-Designing to Understand Equity-Focus in Computational Thinking (CT) Integrated Science Curricula

Broadening participation in computing fields is one important reason to integrate CT in science classrooms. One key step is designing for equitable learning environments that strive to be inclusive and engaging for all learners. To foreground equity-focus in CT-integrated curricula, we undertook a research project in which a collective of CT researchers and teachers examined teacher conceptions of equity and how they operationalize those ideas through modifying a CT-integrated science curriculum. Teachers and researchers worked collaboratively to implement their revisions. We present a preliminary analysis of co-designed curricular units and interviews, illustrating teachers' conceptualizations of equity and their possible implications. Our work contributes to the growing understanding about how teachers can contribute to foregrounding equity-focus in CT-integrated curricular design.

Elizabeth B Lewis Lyrica L Lucas

Discourse in Inquiry Science Classrooms (DiISC) Version 2.0: Developing a Validity Argument for a Secondary Science Classroom Observation Instrument

Measuring inquiry-based science instruction is relevant to on-going science education reform because most science education standards (e.g., U.S. Next Generation Science Standards) outline the practices that promote learning through constructivism, an active learning and inquiry approach. The Discourse in Inquiry Science Classrooms (DiISC) instrument contributes to research on equitable science instruction by addressing constructs on inquiry, oral discourse, writing, academic language development, and use of cognitive learning principles. Since the DiISC was developed within a specific professional development program, we present new evidence associated with aspects of a validity argument for the instrument to be used more broadly in the U.S. and internationally. We used 807 coded science lessons to analyze the factor structure of the DiISC and to investigate its correlation with the Electronic Quality of Inquiry Protocol. We removed items that had low correlations and did not represent DiISC constructs. We also constructed arguments for content, substantive, structural, external and generalizability validity. The revised version is the DiISC Version 2.0, which can be used for observing secondary science teachers' classroom instruction and to provide them with feedback on progress toward building a scientific classroom discourse community that is inclusive of all students, especially underrepresented and multilingual learners.

Tingting Li

Employing adaptation design principles to enhance elementary student engagement in modeling

Adaptation design principles that teachers use for enhancing student learning How can teacher professional learning be designed to promote teacher agency and responsive teaching? The goals for professional learning are multifaceted due to complex demands placed on teachers. While enacting curriculum, a teacher must be equipped to engage students productively. They must improvise teaching to support science practices and build on student experiences and current understanding, create equitable and culturally relevant contexts, and support social and emotional learning. This team of researchers from three universities presents a set of disparate but consequential design principles centered on supporting teachers to adapt curriculum according to context, focused on different teachers and grade levels, but all enacting Project-based Learning. An adaptation design principle is an actionable, evidence-based claim that teachers employ to navigate adaptations so teaching sustains the deeply rooted foundations of productive and responsive science teaching. Paper 1 explains the process for using adaptation design principles to frame Professional Learning. Paper 2 describes design principles for creating equity-centered environments, paper 3 is centered on the design principles that support engagement in developing, using and presenting models, paper 4 shows how adaptation design principles can be used in Professional Learning to leverage adaptations based on culturally responsive teaching.

Sarah C Lilly Anne M McAlister

Elementary Teachers' Verbal Supports during an NGSS-Aligned Unit for Inclusive and General Class Contexts

National frameworks call for the implementation of integrated science, technology, engineering, mathematics, and computer science (STEM+CS) curricular units in classrooms, yet research continues to demonstrate opportunity gaps in learning STEM+CS for students with disabilities. This study investigates how teachers verbally support students in two classrooms, a general class and an inclusive class (i.e., with a larger proportion of students with individualized educational plans), to engage in a Next Generation Science Standards-aligned, STEM+CS unit. Teachers' verbal support for students to understand how (pragmatic) and when and why (epistemic) to use integrated practices was examined during whole-class discussions for the four-week unit in three different disciplinary-focused lessons (i.e., science, engineering, and computer science). Results include that proportions of epistemic and pragmatic verbal support between the two classes were different in the science lesson, somewhat similar in the engineering lesson, and most similar in the computer science lesson. In the science lesson, specifically, students in the general class received support for SEPs in alignment with curricular materials that students in the inclusive class did not. Findings underscore the need for more research to understand what kinds of support teachers need to provide equitable learning opportunities for all students.

Jing Lin Wenting Wei

Revisiting elementary school students' images of scientists

Students' images of scientists entail their identification with the scientific profession and their implicit view of science. Referring to Chambers's DAST (1983), this study mainly uses the drawing method to investigate the images of scientists in students of grades 2, 3 and 4 (n=154). Against the high-tech era with science and technology have penetrated into all aspects of human life, the study finds that students have more serious stereotypes towards scientists. Different grades and genders have differences in these. Findings from this revisiting students' images of scientists call for science education to strengthen the introduction of the scientists' anecdotes to show the humanity in science, which will help students in understanding the nature of science and developing interest in science.

Jing Lin Letong Zhang

Investigation on effect of spatial visualization on scientific modeling in primary and secondary school students

This study takes scientific modeling (SM) as the focus, selecting students from the 4th, 7th, and 10th grades as samples (n = 328) to analyze the effect of spatial visualization (SV) on SM. Using three measurement instruments, this study collects multivariate data and finds that SV has a positive effect on SM. The most apparent positive effect is found in the 4th grade. SM and SV both develop significantly with grade. There are no significant gender difference results in the effect of SV on SM but groups with different science interest have shown significant differences. The findings of this study suggest that SM teaching should integrate SV teaching to enhance students' SM ability in each grade.

Gur Arie Livni Alcasid Michal Haskel Ittah

Please Mind the Gap: Black Boxes as a Pedagogical Construct in the Biology Classroom

Mechanistic reasoning is a tool used to explain, predict and control phenomena. It includes building an explanation, constructed from a set of entities and their features. Research in science education has focused on students' ability to construct complete mechanistic explanations. However, mechanistic explanations are rarely complete either because some of the mechanism is unknown or because it is too complex to mention all of its components. In science, such knowledge gaps are known as black boxes (BB) and are used as a tool, allowing scientists to focus on unknown parts of the mechanism or reduce mechanistic components to create a more productive explanation. In the biology classroom, students who are unable to recognize BB find it hard to integrate new mechanisms into their knowledge base. Furthermore, biology students struggle with the existence of BB explanations co-existing with mechanistic explanations. In search of a pedagogy addressing BB we have adapted guidelines from computer science education. Interventions in computer science education have demonstrated that these can assist students in recognizing and using different levels of information when solving a problem. In this theoretical paper, we argue that these may assist students to better understand biological mechanisms.

Karin Lohwasser Caroline Hadley Long

Conditions Expanding Opportunities for Pre-service Teachers to Learn in Field Placements

This related paper set responds to calls for re-imagining disciplinary learning in science (Warren et al., 2020) and "broadening participation" in STEM (NSF Includes, 2019). Specifically, the papers in this session will explore practices such as anti-deficit noticing as ways to support equitable science teaching and learning. Deficit ideologies can lead researchers and educators to blame students for perceived deficiencies in school rather than attending to the social structures that limit students' opportunities for learning (Peck, 2020; Philip, 2011). Anti-deficit noticing (Louie et al., 2021) is a teaching practice that explicitly challenges these deficit ideologies by (1) identifying deficit frames that limit students' opportunities for learning and (2) shifting toward anti-deficit frames that empower minoritized students. While anti-deficit noticing is becoming increasingly prominent in math education (Louie et al., 2021), less is known about how this practice can be supported in science education. In response, this session will offer an illustrative example of anti-deficit noticing in a secondary science classroom, and it will explore anti-deficit approaches to preservice teacher education and in-service teacher professional development.

Caroline Hadley Long Mark Windschitl

Finding high-quality mentor feedback for science pre-service teachers

The clinical placement, when teacher candidates (TCs) take on responsibilities in a mentor teacher's classroom, is one of the few times when an educator can receive ongoing and discipline-specific feedback from a knowledgeable other. This feedback has the potential to support TCs' learning as they try out teaching practices that emphasize students' ideas, sensemaking, and disciplinary work. However, the quantity and quality of this feedback has often been described as inadequate to support TC growth and as varying greatly between placements. By comparing TCs' stories of feedback that they identified as impactful with examples of feedback that had limited utility, this study identifies characteristics and conditions that make feedback valuable and productive for TCs. Mentors who provided meaningful feedback gave specifics that were generalizable to other circumstances, scaffolded the TC's self-reflection, and created a safe environment for them to learn. Understanding, sharing, and supporting these feedback characteristics can improve their preparation to enact practices that support equitable engagement in science.

Enrique Lopez Vincent Basile

Latinx Students' Sense of Familismo in Undergraduate Science and Engineering

This related paper set is a collaboration of scholars and practitioners from different stages in their careers and explores various methodological, theoretical and pedagogical approaches to move towards justice and equity in science and engineering education. The five papers in this proposal focus on creating opportunities for traditionally marginalized voices to contribute their values and practices

towards the creation of knowledge and solutions for all. The set addresses the question of how scholars, practitioners, and community members can work together in bringing the wealth of experiences and practices of students and their lived realities into science and engineering. In alignment with the NARST presidential theme, the presented scholarship addresses "issues of racial inequities and social injustices related to science" and engineering. The ideas presented in these papers call on us to cherish and invite the richness of cultural, cognitive, and linguistic resources that Black and Latinx students bring for engagement and learning in science and engineering while staying true to their communities.

Gianna Lopez-Colson Joe De Leon

A Critical View of STEM Curriculum from the LatCrit Perspective

Critical race theory practice, which ought to serve as a conduit to liberate the oppressed, is becoming increasingly politicized. The freedom of critical thought and reflection of one's culture, beliefs, and values are constantly under attack from those in power. A critical view of the hidden STEM curriculum and transformative practices are approached from a LatCrit framework. The goal of this paper is to explore asset-based capitals such as community cultural wealth to decolonize curriculum and promote a positive Latinx STEM identity. How are Anzaldua's and Freire's philosophies and theoretical frameworks applicable and relevant to LatCrit in the STEM curriculum?

Christopher Lore Hee-Sun Lee

Integrating Computational Thinking as Part of Simulation-based Scientific Investigations with Volcanic Hazards and Risk

There is a growing need for curriculum materials that integrate science practices with computational thinking practices. To address this need, this research investigated students' use of a blockcode-based computational modeling tool while concurrently learning about tephra hazards and risks caused by volcanic eruptions. We used pre and post tests to examine whether and to what extent students learned about carrying out scientific investigations through computation. We also used a post-activity survey to gauge how students thought about the value of using block coding to carry out scientific investigations. The findings indicate that students made significant gains related to carrying out computationally-integrated scientific investigations. According to repeated measures Wilcoxon signed rank tests, students made significant gains on each of the 11 constructed-response items where they demonstrated their scientific and computational reasoning. Additionally, after each activity was completed, over 80% mentioned a variety of ways coding supported their scientific investigations such as visualizing data and controlling input and output values. Results of this study indicated that it is possible for students to learn CT practices more naturally as part of scientific investigation.

Christine R. Lotter Amanda Gonczi

Impact of Teacher Leadership Skills and Adaptability during Educational Upheaval

This study examined data from 40 teachers, enrolled in an external Teacher Leadership Program at two separate universities, during the 2020-2021 academic year to identify themes regarding whether and how they supported their peers and students, particularly to facilitate science instruction during educational disruptions caused by the COVID pandemic. The research question that guided this investigation was How did the teachers' leadership skills and adaptability impact their schools during the pandemic? Data included interviews, surveys, and observations. A constant comparative method of analysis was used to discern themes. Results include vignettes and frequency data. Themes regarding how the TLs influenced their systems include that they 1) facilitated digital technology use among peers; 2) promoted implementation of best practices; 3) endeavored to increase student engagement and participation; and 4) developed curricular resources to facilitate remote NGSS-aligned instruction. Outcomes suggest that schools should invest resources to develop teacher leaders and adopt administrative perspectives that support teacher leadership as a mechanism to insulate educational systems from future disruptions.

Pamela S. Lottero-Perdue John Settlage

Planning in Science-Integrated Engineering: Kindergartners' Incorporation of Ideas about Inertia in their Design Plans

In this study, we analyze kindergartners' engineering planning as a step in the simultaneous processes of designing and sensemaking. Participants were 28 children from five kindergarten classrooms in three schools who had engaged in an investigation about inertia (result: wood blocks are heavier and easier to move than foam blocks of the same size). They were presented with a design challenge to create a fence using up to 10 wood and 10 foam blocks to contain a small, randomly moving robot. Each participant engaged in a video-recorded cognitive clinical interview about science ideas, to draw/describe/explain their fence plan, and to create/describe/explain their fence. Data were coded to identify evidence of ideas about inertia during science questioning, planning, and creation. All participants shared strong or some evidence of inertia ideas during science questioning. Participants showed strong (36%), some (4%), and no (43%) evidence of inertia ideas in drawn plans; for 18%, evidence was unclear. Students who used ideas about inertia in their plans were more likely to incorporate these ideas in their designs than those who did not. Having students draw/describe/explain their plans provides opportunities for educators to notice students' sensemaking in the design process, including about use of science ideas.

Pamela S. Lottero-Perdue Heidi L. Masters

Elementary Preservice Teachers' Noticing of Scientific Argumentation within Two Online Practice Spaces

Scientific argumentation discussions enable students to engage in critical sense-making with their peers about investigations. Facilitating these discussions is challenging for elementary preservice teachers (PSTs). One reason for this is their limited experience noticing how teachers facilitate and students respond within argumentation discussions. We provided opportunities for 28 PSTs in two science methods courses to practice noticing instances where they had encouraged argument construction and critique in discussions they facilitated. The discussions occurred in two online practice spaces that approximate real classrooms: Eliciting Learner Knowledge (ELK) and Avatar-Based Simulation (ABS). Ten PSTs participated in our study. PSTs noticed a little over half of the researcher-coded argumentation construction instances in both ELK and ABS. PSTs were more likely to notice instances where they elicited students' claims and evidence and less likely to notice when they encouraged students to provide justification. The PSTs noticed prompts asking students if they agreed with one another but experienced some difficulty noticing when they asked students to convince others or compare arguments. These findings have important implications for teacher educators who support PSTs with learning how to facilitate argumentation discussions.

Loucas T. Louca Theopisti Skoulia

Participating in online Teacher Learning Communities as a Tool for Pre-Service Teacher Education

The purpose of this descriptive case study was to better understand the characteristics of Teacher Professional Learning Communities (TPLCs) of pre-service teachers (PsTs). Data derived from 2 TPLCs in which 15 PsTs volunteered to participate, within the context of a pre-school Science Education course they were enrolled in. Our findings suggest that the participants (a) realized the need to work in their TPLCs within a professional culture, (b) regardless of their TPLC members; (c) recognized the usefulness of the TPLC meetings on the fulfillment of their course tasks; and (d) used reflections during TPLC meetings to apply pedagogical ideas that they had discussed in the course. We discuss insights about how this group of PsTs utilized opportunities for professional growth.

Loucas T. Louca

Modeling-based Learning in Pre-School Science: Affordances of Different Types of Student-Constructed Models

Despite its proven added value, Modeling-based Learning (MbL) in science is not commonly incorporated into early grades science education. Following a growing body of research on using MbL in early grades, this multi-case study seeks to provide detailed descriptions of the implementation of MbL with 3 groups of pre-K children engaged in the study of three different phenomena, taught by 3 different teachers participating in a professional development program of pre-school science education. Findings across the different cases suggest that these pre-school children successfully engaged in authentic MbL activities and developed several different types of models using knowledge and experiences, as well as a variety of features of both analogical and mechanistic reasoning, agreeing with prior research of MbL with pre-school children. I use this evidence to argue that (a) different modeling/representation tools may afford different modeling/representation tools using MbL in natural ways of young children learning (e.g., playing). I also discuss implications related to the notion that educators may find it productive to choose among these tools depending on the children's prior modeling experiences and the mechanism(s) to be represented.

Tyler S. Love Julpa Rajyaguru

Integrating Computational Thinking and Engineering Practices to Teach STEM: Examining Students' Attitudes About Physical Computing

There has been an increasing focus on access to computational thinking (CT) instruction for all students in grades K-12. Concurrently, there is a growing emphasis being placed on the integration of CT within authentic STEM contexts. CT is one of the eight science and engineering practices in the NGSS, and NSTA has advocated for the teaching, learning, and integration of CT in STEM. However, there are several methods being used to teach CT, one of which is physical computing. Despite positive observations from previous physical computing studies, there is limited empirical data examining the impact of physical computing compared to other CT instructional methods. This study employed a quasi-experimental design to investigate the physical computing group showed significant gains in various attitude constructs, as well as computer science and engineering items. However, when compared to the control group, there were no significant differences in the computer science or engineering items. The control group also reported significantly higher gains in two attitude constructs. This study presents considerations for integrating CT and STEM to engage students of all backgrounds while developing science and CT literacy.

Benjamin R. Lowell Katherine L. McNeill

Changes in Teachers' Beliefs and Confidence across Multiple Rounds of Professional Development

Teachers' beliefs about instruction and their confidence in their ability to implement instructional reform are important because they can impact the degree to which teachers take up and use new reforms presented in professional development. We surveyed teachers participating in a series of PD sessions around new reform-based curriculum to track changes in their beliefs and confidence over time. From this data, we constructed a quadratic growth model to explain changes over time and teacher characteristics that helped to predict variability in those changes. We found that teachers' confidence and beliefs changed the most after initial PD and then the rate of change decreased over time. In terms of confidence, teachers with more previous PD began more confident and teachers who found the PD more valuable increased faster. These results open up questions about effective modes of PD to continue to support changes in confidence over time as teachers become more familiar with target instructional reforms.

Julie A. Luft Yuxi Huang

What Beginning and Experienced Secondary Science Teachers Notice in Videos of Classroom Instruction

While the professional knowledge of a teacher is important to assess, it may be more important to determine how a teacher views this knowledge in the midst of classroom instruction. The concept of noticing has potential in this area. Drawing upon the work of van Es and Sherin (2008), 17 secondary science teachers watched videos of classroom instruction focused on the NGSS. The teachers were shown approximately 10 minutes of a video and were asked to indicate when they noticed high quality science instruction. The audio recordings of the teachers commenting about the videos were analyzed in terms of the practices and instruction they noticed, along with their framing of the noticing (e.g., comparative, affective, critical). Most of the teachers noticed the actions of the teachers. For beginning teachers, these actions were focused on procedures. Neither group noticed the implementation of the NGSS in a substantial way. From this study, there is a difference in what beginning and experienced secondary science teachers notice during the classroom instruction. This has implications for how teachers should be supported to build their instructional knowledge and practices.

Julie A. Luft Gail Jones

The Handbook of Research in Science Teacher Education: Current and Future Directions for Research

This symposium will specifically report on key conclusions from a recent, comprehensive review of research in science teacher education (specifically, Handbook of Research in Science Teacher Education) and will point to important holes or gaps that are in need of study. Six areas will be addressed that pertain to research in science teacher education. These areas include: Research approaches in science teacher education, Preparing preservice science teachers- core areas (e.g., elementary, early childhood), Preparing preservice science teachers – situated areas (e.g., challenges across the globe, partnerships), supporting the professional learning of science teachers, central tenants of science teacher education (e.g., knowledge, reflection), and emerging areas in science teacher education (e.g., identity, emotions). These different review areas are meant to report on what we know, as well as what will be essential in the future in the field of science teacher education.

Melissa J. Luna

Teachers' planned use of place-based stories rooted in students' everyday experiences of natural phenomenon

Place-based stories can connect students' everyday lives to their sensemaking of natural phenomena (Marin & Bang, 2015). While a place-based story is a type of representation used in science classrooms, a single story can also involve multiple different representations (e.g. photograph, map) requiring students to think across these representations to construct understanding of scientific phenomena. While prior research has demonstrated that different kinds of stories (including place-based stories) can be beneficial to students' science learning (e.g. Mutonyi, 2016), less is known about how teachers consider and craft place-based stories when planning science lessons. This research examines place-based stories taken up by 5th-grade teachers as they co-plan science lessons. Specifically, it seeks to understand why teachers planned to use place-based stories, what these stories contained, and

whether these stories involved different representations students could use to reason about scientific phenomena.

Lisa Lundgren Richard T. Bex

Applying novel methods to characterize an online, science-based affinity space

Characterizing who participates in and contributes to science communication efforts can help extend our understanding of the science education ecosystem, including giving insight into what kinds of communication works for whom and under what conditions. We describe methods for characterizing an online, scientific affinity space using the @PROJECT as our exemplar. @PROJECT is an educational and science communication effort centered on the geological sciences, and uses varied online platforms, including Twitter. Researchers applied an established framework to describe members of the @PROJECT's Twitter users (n = 1113) and analyzed data (e.g. tweets, replies, mentions, and re-tweets) (n = 6538) collected from the community for an annual cycle of activity (January 2020-2021) via social network analysis, topic modeling, and diversity indices. Social network analysis showed a dispersed network with scientists in control of information flow. Topic modeling of tweets with original content (n = 855) generated six topics related to collaboration, connection, and scientific outreach. Application of diversity indices indicated that scientists and education and outreach members were most prevalent across topics. Using these methods uncovers deeper understanding of the community and interactions within the space, which can lead to the development of better science communication efforts in the digital realm.

Mariana Luzuriaga Maria Eugenia Podesta

What science teachers' autobiographies tell us about their own science education and career choices

Teachers' autobiographies are key to understanding their conceptions on education and career choices. We conducted a content analysis of written autobiographies of 70 Argentine teachers involved in a science education postgraduate certification to identify how they characterized their prior science education experiences and in which ways they related them to their career choices. Positively valued formative experiences in science were described as promoting close contact with nature and the application of knowledge, for example, through practical activities. Negative formative experiences were associated with fear and loss of interest, and characterized by transmissive and repetitive teaching with little connection to real life. Interestingly, among the reported formative experiences, those which occurred during secondary prevailed (43%) but among these, 40% were classified as "negative". We also identified three types of role models as influential in the participants' career choices: those who enhanced their interest in science or teaching ("Lighthouse teachers"), those who embodied exemplary teaching practices ("Inspirational teachers") and those who they did not want to imitate ("Anti-models"). These results speak of the importance of the secondary level as a formative stage and of enhancing teacher reflection on their role as models to promote science education as a career choice.

Michelle Möhlenkamp Helena Van Vorst

Investigating Differential Effects of a Digital 'Ladder of Learning' With Adaptive Support in Chemistry

Heterogeneity in students' knowledge, cognitive abilities and interest is a significant characteristic of every school class. Teachers have to deal with this situation when they support students individually. The approach 'Ladder of Learning' starts exactly at this point by structuring lessons and integrating differentiated instruction. In a new project the existing approach 'Ladder of Learning' will be transferred into a digital version including adaptive support with an automatic assignment to knowledge levels and individual assistance. In this way, the advantages of digital media can be used for learning. The digital 'Ladder of Learning' will focus on the topic 'Bohr's atomic model' and will be implemented in grade-nine chemistry classes. In order to investigate the advantages of the digital 'Ladder of Learning', the students are divided into two groups: One group – the intervention group – will work with the new designed digital material with integrated adaptive support presented on tablets. The control group will work with a comparable analogue material with the possibility to get separate adaptive support. The intention of the pre-post quasi-experimental intervention study is to find out which effects a digital 'Ladder of Learning' has on students' knowledge and interest compared to a usual version.

Nessrine Machaka Stina Krist

Changes in Teacher Thinking about Enactment Influenced by a PD about an NGSS-Aligned Storyline Unit

The Framework for K-12 Science Education and NGSS requires significant shifts in how science is taught in K-12 schools (Trygstad et al., 2013). New curriculum materials with a central design principle of coherence from students' perspectives (Reiser et al., 2017) present a shift for teachers in what they are used to seeing in terms of curriculum materials. With this shift, teachers need support and professional development (PD) could be a foundation of systemic reform (Desimone et al., 2002). In this study, we examine the cognitive resources that teachers draw on when thinking about enactment and the changes in teachers' thinking about enactment influenced by the PD experience about an NGSS-aligned storyline unit. Using a grounded approach to analysis, we analyze pre- and post-interviews of two teachers following a 4-day online PD designed about an NGSS-aligned storyline unit. We developed a coding scheme that captures teachers' lesson-images to characterize what the teachers draw on when thinking about enactment. We identified several shifts for how these teachers thought about enactment for science teaching pre- and post-PD and discussed the shift in reasoning about students' knowledge and sense making. Finally, we discuss this study's implications for researchers, teachers, and PD designers.

Lauren Madden Louise Ammentorp

Marine Science, Climate Change, and the NGSS: Lessons Learned from an Initial Round of PD

As the impact of climate change becomes more apparent, it is essential that teachers feel adequately prepared to cover climate change. Research shows that teachers at the K-8 level are often underprepared in this area (Plutzer et al., 2016). Additionally, many science curricula focus almost

exclusively on the one-third of Earth's surface covered in land, rather than the two-thirds covered in water. Understanding marine environments is essential for building a comprehensive perspective on climate systems and climate change. Though the NGSS offer opportunities for helping teachers address these needs, many K-8 teachers are not comfortable implementing these standards (Haag & Megowan, 2015; Harris et al., 2017). After identifying teachers' baseline understanding of marine science, climate change, and the NGSS (Authors, 2021), we modified existing marine science curricular materials to integrate climate change; developed a professional development plan to aid teachers in using these materials and integrating these topics; and implemented the professional development with the first cohort of teachers. Teachers' experiences at professional development were recorded via qualitative survey and project team reflections. We found that the K-8 teacher participants' were able to thoughtfully reflect on their experiences and offer meaningful feedback on the workshops to help us shape and structure our future work.

Benjamin S Mahrer Gary Weiser

Developing a Framework for Identifying Key Innovations in Novel Science Programs: A Learning-by-Making Case Study

The ongoing implementation of the NGSS has spurred new efforts to design science instructional materials, to redevelop science teaching practice, and to investigate student learning trajectories that serve to anchor both. In many cases these new efforts exist as partnerships between content experts, curriculum developers, teachers, assorted stakeholders, and science educations researchers—all of whom bring different perspectives on their product. The logic model approach is a common method for researcher-developer teams to organize the features of policies into inputs, outputs, and outcomes. Accordingly, many funding opportunities for the development or implementation of new programs explicitly require the inclusion of a logic model as part of the overall proposal package. While the logic model can be powerful in helping developers and researchers identify key components and likely outcomes, it is an approach that is limited by the availability of instruments, the complexity of the intervention/policy/program, the theory underpinning the endeavor, and the views of stakeholders regarding what outcomes are meaningful—all of which are subject to change over time. This presentation sets forth a new framework—which we call the Innovations Framework—developed to guide research around a novel science program as the program matured.

Hildah K. Makori

Teaching as enactment of habitus: Preparing preservice science teachers for new ways of teaching science

The goal of the Next Generation Science Standards (NGSS) is to move away from traditional science teaching that has been based on the transmission of ideas and memorization of concepts and vocabulary. However, teaching science differently is challenging because teachers tend to teach the way they were taught, and preservice teachers enter teacher preparation programs with a set of teaching practices acquired during their many years of being in classrooms and observing teachers. Thus,

becoming a science teacher means developing new skills and acquiring new ways of thinking. This study examined how NGSS teaching, ambitious science teaching, and social justice science teaching, which were taught in a science teaching methods course, were enacted by preservice teachers during student teaching. The course was designed to utilize the practices of ambitious science teaching to promote NGSS teaching, as well as social justice teaching. Using the theoretical framework of habitus, structure and agency, the study examined affordances and constraints to the enactment of new science teaching practices. The findings show that, despite all being in the same science teaching methods course, the preservice teachers were on different trajectories in enacting NGSS and AST teaching, and social justice science teaching, thus making evident the power of affordances and constraints outside the university course in shaping their science teaching habitus. The findings suggest that change of habitus requires the support of multiple structures simultaneously and that all affordances and constraints are not equally powerful.

Hamza Malik Stephen B. Witzig

Understanding How an Environmental Educator Identifies & Thinks about Environmental Issues

Communities around the globe are being affected by environmental issues. Education is arguably one of the most influencing factors when it comes to creating awareness & relevance about environmental issues. The purpose of this qualitative research study was to understand in what ways an educator from an environmental education center thinks about & identifies the relevance of environmental issues. The research study was conducted with an educator from a local environmental education center, which plays a dual role to host field trips & nature walks for students (informal science education context) & also partners with a local school(s) as a science content (formal science education context). Narrative inquiry was used to focus in depth on one educator (Greta) to understand her perspective about how she thinks and identifies the relevance of environmental issues. We found that Greta thinks about environmental issues using both her past & current experiences. She believes that the Dale Center for the Environmental issues. She uses informal & formal ways of teaching environmental issues in her methods. Greta uses a more local and personalized approach in connecting these environmental issues with students' life which include their social & cultural aspects.

Kristin E Mansell

Analyzing Teaching Perceptions of Utilizing a District Level Professional Learning Community to Identify Guaranteed Curriculum

Utilizing a broad professional learning community encompassing content and grade specific teachers throughout a district creates an equitable guaranteed science curriculum taught in each classroom regardless of the level of expertise embodied by the teacher. Middle school science teachers can have a conglomerate of knowledge bases ranging from novice to expert which can lower teacher efficacy levels of science teaching. Collaboration through a larger group of pedagogical experts creates a comradery in order to create proficiency rubrics entailing the guaranteed curriculum. This case study examines

teacher perceptions after participation in a broad district level professional learning community endeavor and aims to strengthen the connection between the professional learning community organizational method and science teacher efficacy levels.

Nasser Mansour

The Interplay Between Scientific Evidence, Diversity and Dialogic Pedagogy

This study adopts a sociocultural view of science that views science as a cultural way of knowing, and acknowledges that it is laden with cultural understandings, interpretations, and a language of its own. This study explored the interplay between science teachers' pedagogical beliefs, scientific evidence, and diversity. This paper reports findings derived from qualitative data including interviews and journal field notes observations. The interview sample comprised seven primary school science teachers and nine secondary science teachers. The findings indicated that there was a reliance on dialogic teaching strategies to teach for the school science agenda, but not for the diversity agenda. The findings show that teachers used evidence pedagogy through using their dialogic pedagogy which act as mechanisms to avoid confronting and dealing with diversity, or with the diverse students' concerns. Teachers use these dialogic pedagogies as a 'teacher-led dialogues' tool. Conclusions from the study argue that science teachers need a clear sense of their own views of science in their cultural context in order to be able to understand those of their students and to engage with these views and enhance the use of the dialogic pedagogy by integrating these cultural beliefs into the science discourse. This study adopts a sociocultural view of science that views science as a cultural way of knowing, and acknowledges that it is laden with cultural understandings, interpretations, and a language of its own. This study explored the interplay between science teachers' pedagogical beliefs, scientific evidence, and diversity. This paper reports findings derived from qualitative data including interviews and journal field notes observations. The interview sample comprised seven primary school science teachers and nine secondary science teachers. The findings indicated that there was a reliance on dialogic teaching strategies to teach for the school science agenda, but not for the diversity agenda. The findings show that teachers used evidence pedagogy through using their dialogic pedagogy which act as mechanisms to avoid confronting and dealing with diversity, or with the diverse students' concerns. Teachers use these dialogic pedagogies as a 'teacher-led dialogues' tool. Conclusions from the study argue that science teachers need a clear sense of their own views of science in their cultural context in order to be able to understand those of their students and to engage with these views and enhance the use of the dialogic pedagogy by integrating these cultural beliefs into the science discourse.

Eve Manz Chris Georgen

Collaborative Development of Tools to Address Content-Practice Tensions in Classroom Science Investigations

Elementary science education has the potential to build on students' natural curiosities about their world, promote scientific literacy, and foster positive science identity development. When science is taught with reform-oriented methods such as phenomenon-based inquiry, it can promote equitable

science learning opportunities for students as they see themselves as knowers and doers of science. However, these methods are not intuitive for many teachers, and few professional development opportunities are available for elementary teachers of science. This related paper set, including three studies from across the U.S. and one from Europe, considers the affordances of curricular infrastructureconstrued broadly to include curriculum, curriculum materials, and standards--as boundary objects to support the professional learning of elementary teachers towards enacting more reform-oriented science teaching methods. In each paper, teachers engaged with these boundary objects in collaboration with partners to transform aspects of their science teaching and professional identities. With limited opportunities for professional learning for elementary teachers of science, it is imperative that the field continues to grow in our understanding of how to make a difference in their science teaching practices, and the papers in this set each bring a different and critical lens to this challenge.

Gili Marbach-Ad Patrick Sheehan

Supporting New Research on Teaching Professional Development for Graduate Student: Progression and Personal/Professional Benefits

As critical instructors of undergraduate students, graduate teaching assistants (GTA) need teaching professional development (TPD), however, many graduate programs focus only on disciplinary research and there is a lack of empirical data to guide TPD. We developed a year-long Scholars program to generate empirical research on TPD. Here, we analyzed the research progression and professional benefits of 43 Scholars from the three first cohorts. Out of the 41 Scholars who reported on their progress, eight never received IRB approval, and five never completed data collection, but 28 were in various stages of data analysis, including 16 who completed their projects. Completion was related to a Scholar having prior research experience. Common research barriers included lack of time or institutional support and difficulty with study design. Forty-two Scholars reported personal and professional benefits, including learning more about GTA-TPD, being seen by their department as a GTA-TPD expert, increasing dialogue about GTA-TPD in their department, and expanding (90%) their professional network, a fact supported by our social network analyses. These results can inform other programs training new researchers and suggest that a training program can support increased dialogue and collaboration around critical education issues such as GTA-TPD.

Joey D Marion James Minogue

Was that Productive? Exploring Student-Student Verbal Interactions while Engaged with Virtual Learning Environments about Magnetism

Technology in education is an inevitable evolution in how future learning experiences will be designed. However, they must be carefully designed; our study examined the intersection of technology and productive student talk to address this challenge. In our pilot test of a virtual learning environment (VLE) about magnetism, we incorporated haptic-enabled technology and examined the types of verbal interactions between student dyads. We developed a coding scheme for these types of talk, measured through three main areas: outside activity, management, and productive talk. Our study aimed to evaluate the contribution of haptic feedback on the quality and quantity of student conversation while learning, in particular the levels of productive talk provoked by the simulation. Haptically-enabled simulations produced more verbal interactions overall, but the types of talk were similar to non-haptic partnerships. Our work is positioned to contribute to the growing research base about the design and implementation of highly interactive VLEs for science teaching and learning (VLEs). At a minimum, our analytic approach can be used to gain valuable insights into the types of verbal interactions between students while engaged in science VLEs and contribute to future development of VLEs toward the promotion of productive student discourse and concept development.

Karen Benn Marshall Carmen Bucknor

Understanding the Role of Race and Identity Development in Ethnically Diverse Students at an HBCU

Race and identity often appear inextricably intertwined. Studies suggest that a relationship exists between identity and academic achievement in students at various academic levels (Miller-Cotto & Byrnes, 2016; Oyserman & Lewis, 2017; Syed, Azmitia & Cooper, 2011; Zirkel & Johnson, 2016). The proposed study seeks to consider the role of race and identity in the academic achievement of science and mathematics undergraduate majors at an HBCU and to address existing gaps in the literature. This study seeks to answer the following research question: Is there a correlation between racial and ethnic identity and academic achievement among ethnically, diverse undergraduate students in STEM courses at an HBCU? Findings indicate a small significant positive correlation between racial/ethnic identity and the number of years of high school science completed [r (128) = .215, p=.014]. These findings are consistent with the focus group findings conducted in a sub-set of these participants. Focus group participants were found to be academically proficient in that they had extensive pre-college STEM preparation (e. g. Advanced Placement and honors courses in high school, robust research experiences, and rigorous undergraduate curriculum). Undergraduate students who exhibit strong racial/ethnic identity may create a buffer that benefits them into their long-term career plans.

Stefanie L. Marshall Jenny Sarah Tilsen

Preparing and Retaining Race-Conscious Science Teachers Through Race, Culture, & Coffee

This study examines the impact of intervention developed to disrupt systemic inequality strategically by developing a community that can apply critical pressure toward transformative reflexivity. This community allowed pre-service teachers and early career teachers space to regularly engage in and turn to when they encountered challenging racialized situations in schools, brainstorm how to meet the cultural needs of their students, and how to actively counter systemic oppression within their school context. The diversity of the collective group yields moments of 'otherness' where white participants are de-centered, and the values of the marginalized are centered. The learning community Race, Culture, & Coffee (RCC) was developed in response to a need to develop a community that would disrupt systemic racism. RCC supports the holistic needs of aspiring teachers of color and enhances the racial critical consciousness of all members, given their racialized positionalities beyond teacher preparation. In this study, the authors examine the impact of RCC on white pre-service science teachers. The authors

specifically examine aspects of the learning community that enhanced the racial critical consciousness of pre-service science teachers and how they define their needs in becoming critically conscious.

Stefanie L. Marshall Ain Grooms

Private Industry's Push and Pull: Is Computer Science Really for All?

In 2016, President Obama announced the Computer Science for All initiative, recognizing that computer science is a "new" basic skill in K-12 schools. This resulted in over \$4 billion pledged toward computer science education (CSEd), and growing influence from the private (business) sector. This initiative also created a focus on equitable access for students from minoritized backgrounds with an intent to diversify the computer science workforce. The researchers ask: (1) how has the private sector influenced CSEd?, and (2) how rapidly is the computer science field diversifying? We use publicly available data to examine how policymakers and interest groups drive CSEd initiatives. We also offer implications for researchers and policymakers.

Sonya N. Martin Mauricio Pietrocola

Science Education during the COVID-19 Pandemic

At the onset of the pandemic, we had to adjust to new challenges, the main of which was social isolation. In this symposium, we discuss the innovative theoretical and practical ideas in science education that could support us in coping with the various challenges. Pietrocolo and his colleagues in Brazil used the concept of "risk" to offer an effective source of engagement in the classroom which might play a role in decision-making on contemporary issues in science classrooms. Levrini and her colleagues in Italy borrowed constructs from the "sociology of time" and conducted a study with high school students to find the potential of the dichotomy between "alienation from time" and "time re-appropriation". Nonnekens, in the Netherlands, worked with a team of faculty from two institutions and developed an alternative transdisciplinary research group project that was fully performed online. Johnson in the USA designed an online course about COVID-19 that can teach high school students about the virus, and BouJaoude in Lebanon worked with various educators in the country to alleviate the impact of the pandemic. By bringing those scholars together to share their work and ideas, we aspire to provide a venue for science educators to think and act outside the box during extraordinary times.

Winston E Massam

Implementing Contextualized Science Curriculum and Instruction in Tanzania: The Practice and Possibilities

Contextualized science learning entails teaching science through learners' everyday environment in order to help them find meaning in context by connecting what they learn in school with the phenomena that they encounter in their everyday local environment. In the present ongoing study, a model is designed such that lessons are developed from the mandate science curriculum and executed by taking students from classrooms to their real-world local contexts and then back to classrooms to share what they learned in the real world and how it relates to classroom science. The intension of this pedagogical strategy is to see that learners get the opportunity to actively engage in learning, challenge ideas and concepts, reflect on, and eventually, make connections between the knowledge that they learn in school with what they experience in their everyday life environment. We present in this paper, our observations prior to intervention, which gave us a glance on what took place within classrooms as far as contextualized science teaching and learning is concerned, as well as the initial teachers' and students' reactions towards this way of science teachers and three science streams of approximately 60 students each, all of which, chemistry, biology, and physics are compulsory subjects.

Heidi Masters Vanashri J. Nargund

Fourth Graders' Knowledge of Energy and Environmental Literacy and Application through Flashlight Design

An increase in energy use, light pollution, and landfill waste are negatively impacting our environment. To change the current reality, children need to become energy and environmentally literate to solve these challenges as adults. Engaging children in relevant Problem Based Learning experiences can help them develop the knowledge, attitudes, and behavior necessary to make more informed environmental decisions. In our case study, fourth graders engaged in a series of lessons to develop their knowledge of energy and environmental literacy concepts. They then applied their knowledge by developing a flashlight for a local camping company. After completing the unit, we found the students developed and retained their knowledge of light bulbs (i.e., LED), energy sources (i.e., hand generators), and flashlight materials (i.e., toilet paper tubes) that had a low environmental impact. They also were able to apply their knowledge when selecting materials and designing their flashlight. Some students had more difficulty with explaining the reason for selecting certain materials for their flashlight. These results have important implications for teachers, as they demonstrate the importance of engaging children in Problem Based Learning experiences that allow them to apply and solidify their knowledge for the future.

Clausell Mathis Sherry A. Southerland

A Select Physics Teachers Use of Empathy While Engaging in Culturally Relevant Practices

Reform efforts in science education have asked for teachers to be responsive to their students as sense makers. We introduce a call for teachers to show epistemic empathy, which is the capacity of understanding and valuing someone's cognitive and emotional experience within an epistemic activity. Our case study examines how a high school physics teacher (Sarah) displays epistemic empathy in her

effort to enact culturally relevant pedagogy. As we tracked Sarah's use of empathy, we found other forms of empathy, both humanistic and academic, which supported or inhibited Sarah's epistemic empathy. Our findings highlight particular dilemmas teachers encounter within enacting culturally relevant pedagogy in a physics context.

Henry Matovu Mihye Won

Progression of Students' Interactions over Three Immersive Virtual Reality Learning Activities

This paper-set arises from recent research with 130 undergraduate students enrolled in Chemistry using immersive virtual reality (IVR). Students worked in pairs to investigate molecular structure, polarity, and intermolecular forces for simple and complex molecules. Investigations of students' interactions are based on video recordings, conversation transcripts, conceptual diagrams, and machine-generated location logs. Paper #1 presents an analytical framework of thirdspace to explain the dynamic transactions that take place in the students' physical environment, the designed virtual environment, and the experienced learning in IVR. Paper #2 focuses on how learning the same chemistry concept in different modes - physical magnetic model, computer simulation, and IVR application - afford different spatial explorations resulting in different patterns of spatial, conceptual, and social interactions during their learning experiences in IVR depending on the presence of the researcher's scaffolding. Paper #4 investigates changes in students' interactions within IVR as they experience three separate VR programs over a semester—water molecules and ice crystal formation, stereochemistry and taste receptor, and neurotransmitter and enzyme reaction. This related-paper set offers an insightful and productive way to investigate students' experiences, interactions, and chemistry learning within IVR.

Takuya Matsuura Urumi Hayashiuchi

Critical Discussions in Small Groups to Support the Design of Experiments

Science classes often include students' experiment that are called hands on activities or practical work (e.g., Bennett, 2003). In Japan, when students' experiments are conducted in science classes, they often combine classroom dialogue with discussions and experiments conducted in small groups of about four students. However, the experiment procedures are often given by the teacher and there is not enough opportunity for students to discuss the procedures and its validity (Oshima, 2020). The research question of this study is: How can students' ability to design the experiment be improved by incorporating small group discussions to examine the validity of their ideas in designing their experiment? An exploratory analysis of the impact of repetitive small group discussions showed that many students tended to be able to control variables and describe the perspective of the experiment in the experiment design. However, the results also indicated that there were some students whose level of ability decreased with the next new experiment or with elapsed time. We also need to consider how to encourage students to internalize their experiences, such as communicating what happened in the group to other groups of students (Howe, 2021).

Blanca Puig Mauriz Noa Ageitos Prego

Exploring Secondary Students' Explanations And Ideas On Evolution In A Modelling-based Task

Evolution is a central content in biology education; however, it has been reported to be difficult to learn for students of any age. Research has shown that students' knowledge on natural selection improves when engaging in modelling experiences. This study presents a case study research that engages a group of 10th graders (N=21) in the process of modelling to explain natural selection in the context of mosquitoes' resistance to insecticide. The research questions that drive the study are: 1) How do students explain evolution before and after modelling the process of natural selection in a population of insects when an insecticide is used to control them? 2) Which ideas on evolution are identified in students' written discourse when discussing about evolution during a modelling-based task? The methodological approach is qualitative. All groups show needs-based misconceptions (the individual organism changes to survive) before the modelling task regarding the notion of adaptation. After modelling the process of natural selection, students enrich their explanations about evolution and most of the groups present accurate explanations about adaptation. Using modelling-based tasks in biology education may help students to overcome misconceptions about evolution.

Kirsten K. Mawyer Heather J. Johnson

Exploring the "Wobbliness" of Teacher Candidates' Deficit and Anti-Deficit Framing

Central to equity-focused reforms in science and engineering education is the need to expand what is valued in disciplinary learning, desettling taken-for-granted norms about what counts as valuable ways of knowing, reasoning, and communicating. Creating more expansive spaces for learning science and engineering supports learners to see more of themselves in these disciplines, to bridge their families' and communities' cultural practices and experiences to their disciplinary work, and to disrupt powered racialized and gendered hierarchies in schools. This related paper set examines the contexts of teachers' learning to develop more expansive learning environments in science and engineering. Looking across pre-service and in-service teacher learning communities, this symposium will consider different designs for fostering teachers' learning; explore different lenses for examining how teachers support expansiveness in science and engineering; and investigate the tensions teachers experience as they challenge culturally dominant frames of teaching and learning science. These papers aim to contribute to ongoing conversations about broader sociopolitical contexts of expanding what is valued in science and engineering, taking a teacher-focused lens to understanding how to achieve more equitable spaces for learning these disciplines.

Mariah Claire Maxwell Jason R. Wiles

Cyber Peer Led Team Learning (cPLTL) Supports Women in Science, Engineering, Technology, and Mathematics (STEM)

Peer Led Team Learning (PLTL) is an active learning model that is particularly effective for improving the academic achievement and retention of women in Science, Technology, Engineering, and Mathematics (STEM). Cyber Peer Led Team Learning (cPLTL) is a recently developed variation of PLTL that has been transitioned from a face-to-face environment to a synchronous online setting. Studies have found that PLTL and cPLTL students earned comparable educational outcomes in terms of standardized final exam scores and final course grades. Given PLTL's benefits for women and cPLTL's similarities to PLTL, we were interested in understanding the impact that cPLTL had on women in an introductory biology course at a large R1 research institution. We found strong evidence that participating in cPLTL improves the retention of women in STEM, and that student perceptions of cPLTL are generally high, especially for women. We found that participating in cPLTL may have several additional benefits, such as increased motivation, feelings of belonging, comfort in asking questions, understanding of course content, and support in forming a strong science identity.

Brienne May Jillian L. Wendt

An Investigation of Differences in Students' Interest in STEM Among NGSS and Non-NGSS Implementation

Abstract: This study investigated whether science standard type had a significant impact on student interest in science, technology, engineering, math, and overall STEM. The study was conducted with a sample population of ninth and tenth grade students in the northeastern U.S. enrolled in science classes at school districts implementing the Next Generation Science Standards (NGSS) or the traditional, non-NGSS state science standards. The study also focused on the differences between male and female interest in STEM. The Science Technology Engineering and Math Career Interest Survey (STEM-CIS), a Likert-style survey, was digitally administered to participants and a MANOVA was utilized to compare mean scores on the instrument subscales and overall scores. Keywords: STEM, Next Generation Science Standards, science interest, gender differences

Shana L. Mcalexander Katherine McCance

An Interdisciplinary Approach to Develop Interest for Bioproduct Careers with Historically Underrepresented STEM Undergraduates

Women and students of minority race/ethnicity continue to be underrepresented in many science and engineering fields and access to special programs, mentors, and internships may influence awareness, intention, and persistence in STEM fields. This mixed-methods case study investigates the experiences, beliefs, and career intentions of fourteen undergraduate students from historically underrepresented groups in the United States as they engage in a federally funded grant program, "Sustainable Futures." The program consists of a combination of online courses, workshops, and a summer internship, intended to increase awareness, interest, and diverse participation in bioeconomy-related industries. The expectancy-value theory of achievement motivation theoretical framework guided this investigation of students' changes in beliefs about bioproducts, bioenergy, the bioeconomy, and their career intentions. After completing program activities students maintained highly positive beliefs about the

personal and societal benefits of bioproducts and bioenergy. They expressed greater intention to pursue bioproducts/bioenergy related careers and articulated their career intentions with greater specificity. This study provides insight into the viability of focused academic and professional development programs as a practical method to promote students' awareness, beliefs, and intentions to participate in careers in a sustainable bioeconomy among diverse populations.

Anne M McAlister Sarah Lilly

How Physical Science Doctoral Students Involved in Educational Outreach View and Value their Educator Role

"Service" is central to the mission of many universities and funding agencies; however, STEM graduate students are often encouraged in academic settings to prioritize research over teaching or outreach. Educational outreach programs can benefit both the K-12 students and the graduate student educators. Benefits to graduate students include improved teaching and classroom management skills, increased experimental design skills, strengthened sense of identity and belonging in their field, and refined science communication skills. Understanding the complexities of graduate students' perceptions of their roles as educators is important to better support graduate student educators and the "service" mission of universities and funding agencies. Specifically, we address the research question: How do STEM doctoral students view and value their role as an educator? Eight physical science doctoral students at a medium sized, public research university, all of whom participated in an educational outreach program were interviewed about their experiences in educational outreach. Cross-case analysis of the interview data was used to generate meaning. Themes from the interview data revealed that participants viewed both benefits and burdens to participating in educational outreach, and reported feeling like being an educator was less valued by their institution, their community, and, in turn, themselves.

Katherine McCance Stephanie Teeter

Analyzing an Interdisciplinary Education and Science/Engineering Team's Interactions Using Activity Theory

Interdisciplinary collaborations between different academic disciplines hold the potential to generate solutions to challenges beyond what a single discipline can achieve on its own. However, little is known about interdisciplinary teams of faculty and graduate students and the processes that guide them during collaboration. Using Cultural-Historical Activity Theory, this qualitative study examined a team of U.S. Science Education and Science/Engineering faculty and graduate students as they co-developed laboratory curricula as part of a grant-funded project. Team meeting transcripts were analyzed to understand the nature of the team's activity system and identify contradictions, indicators of potential change or growth. The team's activity system shared an Object, Community, and Outcomes. Contradictions existed in their Tools, Rules, and Division of Labor. The Science Education members were cognizant of curricular and pedagogical concerns, set and enforced agendas, and volunteered for tasks; the PI distributed tasks; the Science/Engineering graduate students focused on lab materials and practical considerations of carrying out labs in classrooms, were given the most work to complete, and

rarely distributed work to others. This study suggests the potential of university interdisciplinary teams to leverage different disciplines' strengths and knowledge as they work toward shared goals.

Katherine R McCance Margaret R. Blanchard

Understanding Scientists,' Engineers,' and Educators' Perceptions of Collaboration and Interdisciplinarity: National Survey Validation and Results

This quantitative study describes the validation and results of two scales measuring scientists', engineers', and educators' perceptions of collaboration and interdisciplinarity. Faculty, staff, postdocs, and graduate students participating in interdisciplinary collaborations between Education and Science/Engineering disciplines completed an online survey. The Collaboration Perceptions (CP; n = 117; alpha = .923) and Interdisciplinarity Perceptions (IP; n =119; alpha = .852) scales were validated separately using Exploratory Factor Analysis. Non-parametric tests, correlation, and linear regression analyses were used to understand participants' perceptions of collaboration and interdisciplinarity and influencing factors, guided by a Collectivist-Individualist Orientation framework. No significant differences were found by demographic factors (e.g., gender, race/ethnicity, discipline), but differences existed by participants' Collectivism orientation. The High Collectivism group had significantly more positive perceptions of collaboration and interdisciplinarity than participants who had Moderate Collectivism orientation. Collectivism orientation was positively correlated with and a significant predictor of CP and IP scores. CP and IP scores were also correlated and significant predictors of one another. This study is the first to provide a broad understanding of what educators, scientists, and engineers think about collaboration and interdisciplinarity. The two scales are valid, reliable tools for researchers and practitioners who study and assess interdisciplinary teams.

Shaugnessy McCann Yamil Ruiz

Identifying the Methods District Science Coordinators Utilize to Monitor and Promote Equity

District Science Coordinators (DSCs) play an important role by supporting the professional development of their teachers. As they work with their teachers, they guide the growth of their beliefs, knowledge, mindset, and instructional practices. These are essential areas when it comes to creating equitable learning environments for all students. In this study we investigated how these science education leaders monitor educational equity within their school districts. As part of a professional development study, DSCs were encouraged to develop strategic plans which included goals, specific objectives, and a plan for evaluating and monitoring their progress towards those goals. Additionally, we conducted focus group interviews where DSCs were asked to reflect on and describe their role in monitoring equity in their district as well as discuss how monitoring equity was present or absent in their strategic plans. Our findings show that few DSCs explicitly address equity as a goal and DSCs found it challenging to be direct in their conversations surrounding equity which affected their strategic planning. This study has important implications for how we provide professional development for DSCs that empowers them to be leaders in equitable education.
Kevin W. McElhaney Anthony Baker

Defining a Research Agenda for OpenSciEd Curriculum Materials

OpenSciEd makes high-quality, standards-aligned science curriculum materials freely available to all of the nation's students and teachers. Rigorous research on these materials is needed to answer questions about the equitable design of materials, impacts on student learning, effective and equitable classroom teaching practices, teacher professional learning experiences, and models for school adoption that address the needs of all students. We engaged 79 science education stakeholders in a series of workshop meetings to generate and prioritize OpenSciEd-enabled research questions, with the goals of centering practitioners' voices, embedding and promoting equity research, leveraging distinctive principles and affordances of OpenSciEd materials, and addressing salient gaps in science education research and practice. Our synthesis of artifacts generated by meeting participants revealed four emergent, crosscutting themes: (1) student agency and participation, (2) promoting the K-12 Framework and authentic science, (3) materials customizations and adaptation, and (4) sustainable adoption and implementation. This synthesis informs the teaching and learning of science by addressing critical gaps that cannot be addressed with typical materials and highlighting cultural shifts in science education praxis, and it is reflective of a field shift toward integration and inclusion of equity concerns within the foundation of education research.

Steven Mcgee Randi McGee-Tekula

Using Hurricane Resilience to Foster the Development of Student Understanding of Ecosystems in Puerto Rico

For school age children on the island of Puerto Rico, the back-to-back hurricane strikes of Irma and Maria were their first experience with the tragedy of hurricanes in Puerto Rico. There is much concern in the general public about the ability of the Puerto Rican forests, like El Yunque, to recover. These concerns reveal common misconceptions about the dynamics of forest ecosystems. The focus of this research is a middle school curriculum unit that engages students in evidence-based modeling of hurricane disturbance using long-term data about population dynamics after Hurricane Hugo. Research was guided by the following research question: How does engagement in the science of disturbance ecology impact students' understanding of ecosystems dynamics? Students completed pre and post assessment understanding of ecosystems dynamics and rated the teacher implementation using the Inquiry-Based Science Teaching survey. Based on a paired t-test, students statistically increased their performance from pretest to posttest with an effect size of 0.22. At the teacher level, the Inquiry-Based Instruction score was a statistically significant predictor of the posttest performance. In other words, these results provide evidence for the hypothesis that the quality of implementation predicted increased understanding of population dynamics.

Christine McGrail Jeanne Brunner

Constructing Science Concept Development: How Design Artifact Changes Reveal Mental Model Changes in Young Children

Engineering design has been suggested as a productive mechanism for promoting science concept development. However, there is insufficient research focused on a deeper understanding of how the engineering design process contributes to science knowledge construction in the early elementary students. This study examined changes to young children's mental models of the concepts of force and motion during the engineering design process. This study also examined how mental model changes were instantiated in the children's design artifacts. We conducted qualitative analysis of video-recorded individuals working through 3 engineering sessions with 26 children ages 7-8 to examine episodes of change to the design artifact as well as the extent and variety of perceptual dimensions addressed at each instance of change. Design artifacts reflected changes to children's mental models as they progressed through the engineering design process. Data indicate that the concept of force is a critical mediator that supports learning about mechanical advantage of levers and projectile motion. Study findings suggest that design artifacts reify science concept development and provide insight into changes to the mental models as they occur during engineering design activities

Valerie Meier John Galisky

How Preservice Secondary Science Teachers Support Sensemaking and Discourse Across Disciplines

The scientific and engineering practices (SEPs) and crosscutting concepts (CCCs) delineated in the Next Generation Science Standards (NGSS) both promote student reasoning and sensemaking and can be understood as a catalyst for providing language-rich engagement in science (Quinn et al., 2012). Consequently, preservice teachers must be prepared to support all students as they engage with the languages of science and engineering in the context of NGSS-aligned lessons. The purpose of this study was to explore how preservice secondary science teachers supported language in relation to the SEPs and CCCs. We qualitatively analyzed edTPA lesson plans and planning commentaries for eight preservice science teacher representing four science domains (biology, chemistry, engineering, and physics). We coded for the eight SEPs, seven CCCs, and five categories of language support (contextualizing language use, helping students interpret language, helping students produce language, organizing instruction, and leveraging students' existing languages). We present the most commonly reported SEPs, CCCs, and language supports and illustrate how they are integrated in specific lessons. Our findings suggest preservice teachers emphasize similar SEPS and CCCs and share common approaches to supporting the languages of science and engineering, though we did find evidence of possible differences between biology and other science domains.

Jeremy W Melton Paichi-Pat Shein

Development of Students' Systems Thinking and Problem-solving through Authentic Aerosol Science Research

An increasingly important aim in education is to develop students capable of addressing complex, interdependent problems. This study integrates theories of situated learning, authentic science research, socioscientific issues, and interdisciplinary STEM education to construct a program for high school students. Drawn from Vygotsky and Dewey's philosophy of social constructivism, the authors developed a framework to incorporate situated learning, authentic science research, and socioscientific issues in fostering environmental sustainable development competencies of systems thinking and problem-solving to provide opportunities for students to transition from newcomers to experts. Using a qualitative approach, the researchers explored the development of the Hybrid Competency Framework using aerosol education as the context with fifty-seven students in Taiwan. The authors found patterns of (1) holistic understanding, (2) authentic and meaningful learning, and (3) mental models and informed decision making. The findings suggest the framework has relevance to high-value learning of systems thinking and for discussions of problem-solving in community contexts and future research directions.

Adi Mendler Dana Vedder-Weiss

Multimodal Analysis of Science Teachers' Facework During Collaborative Video-Based Learning

Science teachers' professional development (PD) can benefit from discussions of classroom videos. However, such discussions might expose teachers to face threat and impede collaborative learning. Studies of facework in teacher collaborative learning have focused predominantly on verbal interaction. We argue that multimodal analysis which also considers embodied interaction reveals meanings that are not accessible when analyzing verbal interaction alone. In our featured case study, a science teachers' PD group discussed a video-recorded science lesson in which a teacher had tried to integrate language literacy. We first analyze five episodes of intensive verbal facework (discursive moves that protect the teacher's public image), using linguistic ethnographic microanalysis to examine nuances of verbal face threat and facework. We then reanalyze these episodes, this time using detailed multimodal analysis to examine embodied face threat and facework. We identify two major ways in which embodied interaction plays a role in face management: (a) mitigating face-threatening verbal moves, and (b) undermining verbal facework. Multimodal analysis thus emerges as key to understanding the challenges posed by video-based discussions. Facilitators who are attentive to embodied interaction can better interpret face threat and facework and therefore better moderate productive video-based PD discussions.

Lucas Menke Jerrid Kruse

Investigating the Knowledge Bases Science Teachers Use When Considering a Socioscientific Issue

While scientific literacy has long been an overarching goal of science educators (Laugksch, 2000), it has more recently become a prominent theme within the Next Generation Science Standards (National Research Council, 2012). In order for students (most of whom will not become scientists) to become scientifically literate, teachers must engage students in socioscientific issues (SSI). Many researchers have analyzed the knowledge bases that individuals use when reading and thinking about a specific SSI.

However, these studies typically focus on an individual knowledge base and its relation to SSI rather than studying the use of multiple knowledge bases. Our study used a think-aloud protocol to analyze the knowledge bases that in-service secondary science teachers use when reading about an SSI. Participants were given a news article about the use of road salt and asked to read it while also verbally expressing their thoughts regarding the article. Results from this study indicate that participants drew most heavily from their understanding of technology and the media. The findings from this study may help science educators better engage aspects of scientific literacy that are often overlooked in science classrooms.

Deepika Menon Deepika Menon

Investigating Preservice Secondary STEM teachers' Reflective Practice in a Microteaching Context

Reflective practice is an important component of preservice teacher education programs and is frequently used during field experiences; however, less is known about reflective practice in microteaching. This qualitative case study examines preservice secondary STEM teachers' reflective practices after their microteaching experience in a STEM methods course at a large mid-Atlantic public university. Particularly, the study investigates two reflection approaches, a written reflective journal and a video-mediated reflection on the same microteaching episode. We used content analysis to identify and compare the salient features in 27 preservice secondary teachers' video-mediated and journal (non-video) reflections. Our analysis led to three categories representing the salient features from the two sets of reflection – teaching strategies to foster student learning, student engagement and classroom discourse, and teacher personality and non-verbal communication. The video-analysis design allowed preservice teachers to reflect on their teaching in both a critical and comprehensive manner. Our findings provide valuable insights for teacher educators to make informed decisions about selecting reflection approaches that fit the course context and the goal of reflection and ways different reflection approaches create opportunities to support reflective thinking.

Alison Mercier Tierney Hinman

Investigating Pre-Service Teachers' Noticing of the Cultural Foundations of Children's Scientific Explanations

Effective science teaching requires that preservice teachers notice and attend to students' everyday cultural and community knowledge to support students' sense-making of canonical science ideas. This design-based study investigated preservice teachers' (PSTs) understandings of elementary students' explanations of scientific phenomena, and the discursive moves teacher educators can enact to expand PSTs' noticings and interpretations. Data sources included classroom observations and PSTs' reflective notebook entries. Findings indicate that the tandem nature of providing guided focus and employing expanded discursive moves supported PSTs' recognition of and attention to students' non-normative ideas.

Alison Mercier

Elementary Teachers' Agency for Teaching Science and Engineering when Working Within and Against School Structures

Despite calls to establish science as an important component of the elementary school curriculum, science and engineering are almost completely ignored or approached through traditional teachercentered instructional methods in many elementary schools due to the relationship between school structures and teaching. Adding to that is a lack of literature that takes a non-deficit view of teachers committed to teaching science and engineering in high-needs, elementary classrooms to provide a robust portrait of these agentic teachers. We asked: How do teachers in urban emergent schools with strong commitments to robust science and engineering instruction narrate the nature of their STEM-linked agency over a school year? With STEM journey map and interview analysis, this narrative inquiry explored the thinkability and doability of science and engineering in the classrooms of 18 elementary teachers. Teachers' agency was visible as STEM-linked agency when science and engineering were both highly thinkable and doable. Teachers narrated this as a fluid phenomenon that ebbs and flows when they dynamically and creatively work within the contexts of high-needs schooling to create change and align practice with professional vision in innovative and responsive ways.

Alison Mercier David Segura

Analytic Approaches to Studying Identity Work Longitudinally

Few studies examine identity over time. Longitudinal studies are time-consuming, expensive, and difficult to do because of the difficulty of finding and/or following up with past research participants. A further conundrum for identity studies is that, in claiming its situated, fluid nature, there is a danger in rendering the concept meaningless. If one's identity shifts with each new context or from moment to moment, then how should "it" be studied? Where is the coherence and continuity of self, and how can we account for that without diluting the complex processes of moment-to-moment becoming? In this session, presenters provide their insights in navigating these and other challenges of longitudinal identity studies. The symposium explores current trends in longitudinal identity research and to provide insights into how researchers critically look at identity while navigating challenges associated with longitudinal identity studies. The symposium represents work from scholars working in different countries and regions of the United States. The work focuses on student, teacher, youth, and adult participants, and uses qualitative and quantitative methods.

Avraham Merzel Yaron Lehavi

Assessing Coherence Understanding of Energy as a Crosscutting Concept

Assessment of learning science usually focuses on the alignment of students' achievements with certain understanding standards. Following the constructivist framework, this study focuses on diagnosing the

coherence of mental models–concept images that students and teachers construct regarding energy as a crosscutting concept. Coherence can be a measure of how well such mental models are linked to scientific ideas, experiences and explanations of new situations. Assessment of crosscutting concepts themes that cross disciplinary boundaries - can support both a coherent cognitive knowledge and science curriculum. In this respect, Energy poses a rather big challenge. In this study, we designed a questionnaire to assess the coherence of understanding Energy as a crosscutting concept. We collected responses from students and teachers of different levels and scientific disciplines. Our findings suggest that a calorimetric approach, which is less common in high school curricula, can assist teachers and students in instilling Energy as a crosscutting concept. Applying the method of crossing responses to different questions revealed that the respondents' mental models of energy encompass many variations of scientific incoherencies. This method can be used also to assess curricular coherence.

Gunkut Mesci Eda Erdas Kartal

Teaching of NOSI in Outdoor Learning Environments in the Period of Covid-19 Pandemic

The purpose of the study is to investigate pre-service teachers' nature of scientific inquiry (NOSI) views after an online teaching of NOSI in the outdoor learning environment during the COVID-19 Pandemic. This is a qualitative study of examining the developments of pre-service teachers' NOSI views during a 14-week implementation in online outdoor learning environment. 50 pre-service teachers participated in this study, and each participant's views of NOSI and changes were investigated throughout open-ended questionnaire, follow-up interviews, reflection essays, lesson plans, and online meetings as a multiple comparative case study. At the beginning of the study, it was found that the pre-service teachers had mostly a naive or mixed understanding regarding the targeted NOSI aspects. After 8 weeks of online teaching at the outdoor learning environments, a positive improvement was observed in the pre-service teachers' NOSI views. At the end of the 14 weeks implementation, almost all of the participants had a dramatic improvement in their views of NOSI. It is suggested that teachers' knowledge and awareness towards NOSI should be improved. The study might be of interest to the science education community by showing examples of how to use explicit reflective approach with socio-scientific issues in outdoor learning environments.

Canan Mesutoglu Dürdane Dury Bayram-Jacobs

Learning in Multidisciplinary Teams in a Challenge-Based Learning Course

In 21st century classrooms, learners should be raised to appreciate the importance of science and engineering in real life contexts and to engage in discussions on the global challenges facing humankind. Challenge based learning (CBL) courses has merit in accomplishing these goals by helping students generate innovative solutions to authentic, complex problems. The fundamental characteristics of CBL include real-world challenges, collaboration and multidisciplinarity. The presented work describes a newly designed CBL course where applied physics and mechanical engineering students worked in multidisciplinary teams. A case study was conducted to: a) explore learning gains in relation to multidisciplinary teamwork and b) identify facilitators of and barriers to successful multidisciplinary

teamwork. Data included interviews, observations, and design products. The results indicated gains in student learning mainly in mechanical engineering related concepts and methods. The findings also yielded major factors that influence multidisciplinary teamwork: a) setting strong disciplinary connections to the challenge task, b) receiving tutor guidance, c) prior knowledge, d) making explanations to team members from the other discipline, and e) exchanging science and engineering perspectives. Implications contribute to future research and thinking about designing similar learning environments while improving student learning in multidisciplinary teams.

Allison T Metcalf Shannon G. Davidson

The Importance of Epistemic Empathy for Equitable and Rigorous Science Teaching

In this work, we offer a literature review of empathy in order to call attention to what we refer to as epistemic empathy as an important concept to consider in teacher education. Empathy is important to manifold phenomena in education, and much of the existing research has centered on the role of empathy in supporting teachers' understanding and awareness with regard to students' social realities and cultural backgrounds. While this work is extremely important for science teaching, we contend that a critical element is missing from this line of work, namely that of teachers' empathizing with learners' epistemic experiences, or experiences centered on the construction and refinement of knowledge in science. We define epistemic empathy as one's capacity for tuning into and appreciating someone else's intellectual and emotional experiences within epistemic activities and we argue that such empathy is essential for the enactment of rigorous and equitable science instruction. We end with a discussion of the theoretical and practical implications of construing epistemic empathy as a target for teacher learning.

Hanno Michel Ute Harms

Modelling and Assessing Climate Literacy – Development and Implementation of a Knowledge-in-Use Assessment Instrument

Several studies show that students often lack conceptual knowledge and show multiple misconceptions when explaining climate change (Boyes & Stanisstreet, 1993; Flener-Lovitt, 2014; Shepardson et al., 2011). Hence, it is often argued that science education should focus on conveying sufficient conceptual knowledge about climate change, its causes, consequences, and potential ways of adaptation and mitigation. However, besides scientific content knowledge, decision-making and the intention to act in a climate-friendly manner seem also to be influenced by non-scientific factors such as attitudes and value attribution (Dietz, Dan, & Shwom, 2007). The USGCRP (2009) thus promotes to focus education on climate literacy, which includes specific knowledge about climate change, as well as skills and attitudes relevant to the topic. So far, studies examining the impact of climate literacy on actual decision-making are scarce, and the general picture about other factors that contribute to young learners' conceptions of climate change – including the media, family, peers, but also emotional attachment and risk perception – remains somewhat unclear. In this related paper set, we aim to elaborate how climate literacy can be

modelled and assessed, how it can be promoted through meaningful instruction, and how teacher professional development can contribute to this.

Jamie N. Mikeska Heena R. Lakhani

Exploring the Nature of Challenges Preservice Elementary Teachers Experience about Matter Content and Content Teaching

Despite the importance of developing elementary science teachers' content knowledge for teaching (CKT), there are limited assessments that have been designed to measure the practice-based components of their CKT at scale. This research study was designed to address this gap by developing an online assessment to measure the practice-based components of elementary preservice teachers' CKT about one high-leverage science content topic: matter and its interactions. In this study, 86 elementary teachers (79 preservice and 7 in-service teachers) participated in cognitive interviews to examine the knowledge and reasoning they used when responding to CKT matter assessment items. Study analyses identified and described the nature of the content challenges and the content teaching challenges participants encountered. Findings showed that when encountering difficulty with the science content, some participants struggled to use relevant and sufficient evidence or understanding of scientific concepts to reason about or justify science tasks, leverage relevant examples of scientific phenomenon, and draw upon science vocabulary. When experiencing difficulty with the content teaching aspects, findings showed that some participants struggled with connecting to key scientific concepts, attending to the given instructional goal, and recognizing grade-level appropriateness. Implications for using CKT items to identify science teachers' challenges are addressed.

Jamie N. Mikeska Heather Howell

Using a Simulated Classroom to Prepare Elementary Preservice Teachers During and After the Pandemic

Educator preparation programs experienced extreme challenges during the COVID-19 pandemic, as many universities and K-12 schools moved to fully online or hybrid instructional models. These changes limited teacher candidates' opportunities to engage in classroom-based practice teaching experiences. In this study, we examined the usability and viability of integrating simulated teaching experiences, which occur in a virtual classroom environment consisting of five student avatars, into elementary science method courses during the COVID-19 pandemic. This study uses qualitative content analysis of survey data and a focus group interview to identify patterns and themes in how four elementary science teacher educators and 49 of their elementary preservice teachers perceived the use of this tool within elementary science teacher educators and the opportunities and challenges this tool afforded during the pandemic and possibilities for use in the post-pandemic era. Study findings suggest that these elementary science teacher educators and preservice teachers perceived the simulated teaching experience as valuable for supporting teacher learning, addressing COVID-related challenges, and tackling perennial challenges in science teacher education. Implications for leveraging lessons learned post-pandemic and a discussion of key factors that may support and hinder the use of such tools within elementary science teacher education are included.

Jamie N. Mikeska Jonathan Steinberg

Using Simulated Classrooms to Examine How Formative Feedback Impacts Elementary Teachers' Ability to Facilitate Discussions

The purpose of this research study was to examine in-service teachers' perceptions about and use of two different types of written formative feedback designed to support them in developing their ability to engage in one core teaching practice: facilitating discussions that engage students in scientific argumentation. This core teaching practice is one that has been nominated as important for building students' scientific literacy and has been perennially difficult for teachers to learn how to engage in successfully. This study used an online, simulated classroom made up of five upper elementary student avatars as the practice-based space where the participating in-service teachers facilitated two discussions. Following the first discussion, each teacher received one of two types of written formative feedback (specific feedback or scoring level feedback) based on their discussion performance. The study examined the teachers' perceptions about and use of the feedback to help them improve their ability to facilitate argumentation-focused discussions, as well as examined whether the two types of feedback differentially related to any improvement observed. Findings suggest that the use of specific or scoring level feedback can serve as one valuable mechanism to support improvement when using digital approximations of practice with elementary science teachers.

Luciana Martiliano Milena Danusa Munford

Writing Science in English at College: Non-Anglophone Students' Participation in Epistemic Practices

This study investigates how non-anglophone college students in an introductory science course taught through EMI participate in epistemic practices as they write a scientific paper in English about an inquiry project they developed. Informed by previous studies, the analysis focuses on the rhetorical movements and epistemic levels present in the students' texts. These aspects provide insight into the students' participation in epistemic practices. The study took place in an Introductory General Science course taught in English in a university in southeast Brazil, where 51 Brazilian-Portuguese speaking students elaborated papers in English about their inquiry projects. We analyzed the Introduction and Objectives of two texts, selected to provide the maximum variation in data. Results evidenced that the students participated in epistemic practices of science for the organization and elaboration of scientific texts in a foreign language, but also that they established significant relationships between Science, everyday life, and pop culture. Thus, it is important to develop new analytical tools that contemplate other cultural practices immersed in foreign language scientific writing in courses at the college level.

Alison R. Miller Lauren P. Saenz

Using the Scientific and Engineering Practices Observation Protocol (SciEPOP) to Explore Play-based Early Learning Environments

This paper reports on the development and use of the Scientific and Engineering Practices Observation Protocol (SciEPOP) to explore the effects of physical space,

materials, and teacher pedagogy on children's engagement with scientific and engineering practices (SEP) through play. Working with four different preschools, researchers identified relationships among specific spaces, pedagogical strategies, and children's patterns of engagement with SEP. These relationships suggest significant gaps in children's opportunities to engage in play and therefore deepen their enactment of scientific and engineering practices. In this paper, the authors offer an overview of the development and validation of the SciEPOP instrument as well as evidence in support of the centrality of play to children's emerging scientific understanding, and raise questions about the relationship among space, materials, and pedagogy in support of rich play-based learning environments.

Emily C. Adah Miller Susan K. Codere

Using Adaptation Design Principles to Support Teacher Agency in Professional Learning

Adaptation design principles that teachers use for enhancing student learning How can teacher professional learning be designed to promote teacher agency and responsive teaching? The goals for professional learning are multifaceted due to complex demands placed on teachers. While enacting curriculum, a teacher must be equipped to engage students productively. They must improvise teaching to support science practices and build on student experiences and current understanding, create equitable and culturally relevant contexts, and support social and emotional learning. This team of researchers from three universities presents a set of disparate but consequential design principles centered on supporting teachers to adapt curriculum according to context, focused on different teachers and grade levels, but all enacting Project-based Learning. An adaptation design principle is an actionable, evidence-based claim that teachers employ to navigate adaptations so teaching sustains the deeply rooted foundations of productive and responsive science teaching. Paper 1 explains the process for using adaptation design principles to frame Professional Learning. Paper 2 describes design principles for creating equity-centered environments, paper 3 is centered on the design principles that support engagement in developing, using and presenting models, paper 4 shows how adaptation design principles can be used in Professional Learning to leverage adaptations based on culturally responsive teaching.

Emily C. Miller Emily Reigh

Science, Language, and Equity Practices: How Teachers Respond to Professional Learning Focused on Epistemic Agency

Professional learning for teaching Multilingual Learners (MLLs) in science needs to respond to the shifting landscape that describes student learning as driven by engagement in science practices for sensemaking, and teachers as supporting the dynamic language of sensemaking. This design-based research project, with 5 elementary science teachers, designed to promote epistemic agency of

teachers, researchers introduced theories about science and language, including the general views of equity (Gutierrez & Rogoff, 2003), the concept of language resources (Van Lier, 2006), and the raciolinguistic perspective (Rosa & Flores, 2017). Teachers were invited to discuss and critique these theories and develop related tools that they could use in their teaching. Exit interviews showed that teachers responded to the practices and ideas presented in the PL as valuable to their teaching. The codes excerpts underscored on tool development as being most highly associated with epistemic agency.

Jaimie Lauren Miller-Friedmann Nicola Wilkin

Effectiveness and Inclusivity: determining best physics and astronomy departments for women of colour

Women of colour are deeply underrepresented in some STEM disciplines at the undergraduate level. However, little is known about the finer details of this underrepresentation: for example, the kinds of institutions where women of color are markedly underrepresented and those in which they thrive; institutional policies and practices that lead to inclusive cultures; benchmarks about what constitutes an above-average departmental performance of intersectional inclusion. This quantitative study created an 'effectiveness' score for physics and astronomy, mathematics and statistics, and computer science departments in how well they recruit, retain, and graduate women of colour. These scores were then ranked; in this paper we report the top ten physics and astronomy departments for women of colour. These universities are very diverse, and the only quantitative factors in common are their levels of inclusivity and academic rigour. We conclude by suggesting that future qualitative research is necessary to determine best practices at these departments; we believe these results are not contextualised to UK universities, but are universal. Best departments for women of colour seem to be inclusive departments that are rigorous in academic standards, thus making their graduates employable or prepared for postgraduate degrees, and making their undergraduate students comfortable and welcome.

James Minogue Emily Brunsen

Tracing the Development of a Haptically-enabled Science Simulation (HESSs) for Force and Motion

This proposed poster will chronicle the Year 2 efforts of a federally-funded research project that uses an emerging technology, haptically-enabled science simulations (HESSs). Our work integrates the Novint Falcon force-feedback device and the Unity[®] game engine to create our simulations. We employ our HESSs as a vehicle to isolate and describe changes in teachers' capacity to teach foundational physics concepts. We are interested in the influence of haptic-force feedback on the development of a functional understanding of how their students learn about force and motion.

Jim A Minstrell Philip Hernandez

Mining the Potential of "Wrong Answers" in Item Pairs to Describe Students' Alternative Thinking

Research has shown that knowledge of learners' ideas and the ability to anticipate and address alternative thinking has more influence on student performance than a teacher's own content knowledge (Sadler et al.). Yet, information about the status of students' understanding and their specific learning needs is commonly relegated to informal, low stakes classroom measures with little attention to validity or reliability. This paper presents findings from the analysis of dependent pairs of items designed to measure students' conceptual understanding in physics. The study is nested within a larger parent study and draws on a database of more than 1600 secondary students' responses to multiple-choice items targeting knowledge of force and motion. This paper demonstrates how paired items with different forms of representation, asking about the same construct within the same context can provide valid and reliable information about students' alternative thinking. The paper also illustrates the successful development and interpretation of assessment items that potentially diagnose student thinking and understanding in a more nuanced way than "right or wrong," a way that can better serve instructional decisions and the learning needs of students.

Andrea Moeller Petra Bezeljak

Understanding Middle School Students' Connectedness with Nature

Fostering pro-environmental behavior in order to achieve a sustainable society is one of the goals of Education for a Sustainable Development (ESD) worldwide. Connectedness with nature is known to positively correlate with pro-environmental behavior. Hence, it is important to know more about the connectedness with nature in students and gain insight in reasons and concepts. Here, we investigated 1) how middle school students are connected with nature, 2) how they describe the reasons for their level of connectedness, 3) in which way reasons and level interconnect and 4) whether personal habits like the frequency of spending time outdoors influence students' connectedness with nature. 676 students grade 6 of ten urban middle schools completed a questionnaire which included the graphic single item "Inclusion of Nature in One Self" (INS), accompanied by the request to explain why they chose their specific INS-level. Also, personal data, such as hobby or frequency of nature contact was collected. Results indicate that students with high INS levels often stated positive attitudes towards nature and reported higher frequencies of contact with nature as the reason for their connectedness with nature. More results will be presented and discussed in detail in reference to ESD at the NARST conference.

Ashwin Krishnan Mohan Gregory J. Kelly

Learning in trajectories of participation: Nature of Science and Temporality in the Nature of Scientists

At the level of graduate and post-secondary education, the learning outcomes of science education frameworks need to account for the ways in which students come to participate within communities of practice with contextually negotiated, emergent, and dynamically evolving epistemic cultures. The change in analytical focus, from the community to the individual, requires us as a community to reckon with the epistemological underpinnings of what counts as knowledge, and what is required to be known

for individual scientists to negotiate their membership and participation within scientific communities over time. This paper elaborates on this change in focus to build on the connections and relations between two existing frameworks, the FRA approach to NOS and the NOSist framework, using data from an ethnographic investigation of two scientific communities. It is hypothesised that the nature of science varies across time and is taken up differently by different scientists with their own natures of scientists. We highlight ways in which the switch in analytical focus to the individual NOSist offers new ways of considering aspects of the NOS that have been identified in the FRA model, and additionally also offers radically new practices at the level of the scientist that ought to be distilled into learning outcomes at secondary and post-secondary STEM education

Audrey Mohan Michael J. Novak

Designing middle school science curricula 'by states, for states'

In this proposal for a related paper set, the authors of the individual papers are science education researchers who are engaged in the development of instructional materials designed for broad use across the U.S. The premise of the project is that science education researchers bring a valuable set of perspectives, knowledge, and skills to this work. At the same time, the process of developing instructional materials for widespread use across the diverse school settings that are found in the U.S. has called for the participating researchers to develop new perspectives, knowledge, and skills. Throughout this paper set, we explore the challenges of bringing researcher perspectives and research-based approaches to the design of instructional materials for broad use. We do so through case studies in which we describe how we have been able to apply theory, findings from prior research, and research methods to achieve the goals of the project. We also describe how the challenges of the project have required us to go beyond the knowledge, tools, and techniques that we brought to the project, typically through collaboration with others whose understanding of science teaching and learning is rooted in other training pathways, professional experience, and personal histories.

Olayinka Mohorn

Science Classrooms as Hostile Environments for Black Female Science Teachers

Black women's political and social position in the United States has afforded them with a unique set of experiences as American citizens. It has been shown that Black women are typically viewed through a narrow lens of salient, racialized and gendered stereotypes, and as a result struggle to be seen as capable professionals and contributing members of society (Collins, 2000; Harris-Perry, 2013; Jones & Shorter-Gooden, 2003). Informed by a sociocultural framework of identity construction coupled with a Black feminist lens, I employed a narrative inquiry approach to learn from the experiences of five Black female veteran teachers while teaching in urban secondary science classrooms. Study findings suggest that Black women experience regular instances of microaggressions while working as science teachers. The teachers in this study shared that were victims of microaggressions because of their positionality as a Black female teacher of science. Implications of study findings include the need for school districts to improve job conditions for Black female science teachers by educating administrators about Black

women's experiences with microaggressions. This will aid them in properly interpreting classroom practices they observe and more deeply understanding how urban school environments can serve as hostile spaces for Black female science teachers. These understandings can be used to create school structures that are tailored to combat issues unique to Black female science teachers.

Carlos Mometti Tanja Tajmel

Physics Education Curriculum from the decoloniality lens: a Brazilian case study

Considering the teaching process also as a social process framed by politics embedded in curricula, we can say that the curriculum brings with it cultural aspects that are embedded in a colonization process still in force. Such a process, however, is characterized by the reproduction of cultural elements from those in power over the oppressed. In this sense, it is justified to study what these cultural elements would be and what processes and practices are offered by decolonial theory, when we assume Brazil as the context of analysis. Thus, we seek with this work to present an analysis on the theme of cultural decolonization in Physics Education and its influences with regard to the construction of a scientific cultural nationality. To explore these questions, we started an analysis of the Brazilian Science Education curriculum (Physics). With this investigation, we hope to understand the cultural lenses that act as a colonizing operator on the set of scientific standards and scientific Brazilian representativeness.

Sierra L. Morandi Claudia Hagan

Exploration of Epistemic Orientation towards Teaching Science in a Longitudinal Professional Development Study

Current reform efforts in science education focus on creating environments where students grapple with and negotiate their own understandings and mechanistic explanations of scientific phenomena by using their knowledge of disciplinary content and science practices. In order to support this reformed vision, effective professional development (PD) for science teachers is critical. If PD is to shape teachers' practice, teachers must experience a change in attitudes and beliefs. The research presented here explores the epistemic orientation of two secondary science teacher cohorts who were supported in a longitudinal professional development study. The epistemic orientation toward teaching science survey was administered at three time points for each cohort and paired sample t-tests were performed to analyze composite and dimensional scores. Our analysis revealed that change in epistemic orientation occurred for teachers who engaged in two years of supportive PD, but that one year of support was not sufficient to engender change in epistemic orientations. These findings further support the need for continuous, high-quality, longitudinal PD when the goal is a shift in science teachers' epistemological beliefs and teaching practices.

Nancy Moreno Al

Alana Newell

Implementation of the ALL for Science Framework Across Three Grade Levels

Supporting students' development of science-specific disciplinary literacy may help them make sense of science content, as well as help them begin to connect the work of scientists with their own identities. We developed the Literacy and Language (ALL) for Science framework for curriculum development to support the development of these skills through three daily components: 1) Science Investigations – science inquiry activities; 2) Reading Mini-lessons on a strategy related to reading science expository text; and 3) Science Inquiry Circles – small, collaborative group work focused on applying science-specific reading strategies in text-based research. We then created and field tested units using the framework for grades 1-3 in a large, urban area. The current study investigates the effectiveness of the framework components across the grade levels. Findings indicate that each unit was considered effective by field test teachers, and that most would implement units using the model in the future.

Patricia D Morrell Jana Visnovska

Australian Primary School Students' Understandings about the Nature of Scientific Inquiry

Internationally, understandings of scientific inquiry (SI) are included in science education standards and curricular documents. While there have been investigations about 7th and 12th graders' understanding of SI, there is limited knowledge regarding primary school students' understandings of SI. The purpose of this project is to get the baseline data on what primary school students understand about SI. Our sample was 111 third graders who completed the 'Views About Scientific Inquiry-Elementary' (VASI-E) open-ended instrument and a follow up interview with 21 students. On a scale of naive, mixed, informed, we found that most primary students had mixed/informed understandings of SI beginning with a question, procedures being guided by the question, conclusions consistent with the data, and explanations developed from data and prior knowledge. In contrast, the majority of students had naïve/mixed understanding of the use of multiple designs to solve investigation. This study was part of an international effort led by Judith and Norman Lederman (who co-authored the VASI-E) involving researchers from 37 countries.

Terrell R. Morton Yejun Bae

When Disaster Strikes: How New Majority Students Navigate STEM During a Global Disruption

This study examines the influence of COVID-19 on New Majority college students' STEM learning experiences. Using Phenomenological Variant Ecological Systems Theory to analyze open-ended survey questions gathered from 13 students, we ascertained factors of the broader environment that inform their motivation and engagement in STEM during the pandemic. Findings detail how shifts to both the classroom and life structure prompted decreases in students' motivation and negative increases in their social-emotional well-being. Implications for how instructors and researchers can support New Majority students' STEM learning and engagement during crises are provided.

Terrell R. Morton Angela White

Designing and Implementing Virtual Black STEM Counterspaces to Elevate Black Learners

This symposium features five presentations that discuss the design and implementation of virtual, Black STEM Counterspaces for Black learners along the K-20+ continuum during the COVID-19 pandemic when social-distancing rules restricted in-person gatherings. Across these papers, the authors share the purpose of the counterspace, how and why it was designed, and its impact on Black leaners. Specific insight on the key social-cultural components of the various learning environments and how they influenced Black learners' motivation and engagement in STEM are shared.

Alexandria Muller Marco Barron

Student Depictions of the Engineering Design Process

Engineering is now included at all levels of K-12 education due to the introduction of the Next Generation Science Standards. This is important for helping to bridge the STEM pipeline; however, linear models of the engineering design process that have historically been taught in schools does not match the non-linear and iterative design process used by professionals. Through a Research-Practice Partnership between a university in southern California and a local interactive science center, we developed engineering-focused curriculum that introduces students to a non-linear engineering design process through hands-on activities. After participation, students were asked to draw a representation of the engineering design process. In this paper, we explore how these students depicted the engineering design process and consider the implications for future engineering curricula.

Rianna T. Murray Kelsey McKee

A Curricular Model to Train Doctoral Students in Interdisciplinary Collaborative Research at the Food-Energy-Water Nexus

Recent research recognizes that food, energy, and water (FEW) systems are inextricably linked and emphasizes an interconnected approach to policy, science and practice focused on FEW nexus solutions. Hence, there is an urgent need to train the next generation of FEW nexus professionals in interdisciplinary research and systems thinking. While this training is especially important at the graduate student level, traditional graduate training often occurs in academic silos whereby students are trained in discipline-specific theory, methods, and applications. Here we describe one curricular model for training doctoral students to work on issues at the FEW nexus. We provide a two-course sequence to a cohort of students over a calendar year - the first course provides an experiential introduction to systems thinking at the FEW nexus, and the second is a data practicum where students collaborate on a FEW research project. We will present data collected from three consecutive iterations of this course sequence. Our findings indicate that this model provides students with the opportunity to learn FEW nexus content using a systems thinking framework and practice interdisciplinary collaboration via a tangible research product. This model could be implemented in a variety of academic settings and at different educational levels.

Emmanuel Mushayikwa Magdeline Mmapaseka Stephen

The impact of technical Science in increasing access to Stem education for vocational careers in South Africa

This paper investigates the impact that Technical Science, has had on the performance of Physical Science learners and on their access to STEM vocational careers in South Africa. In a bid to address barriers to access technical vocational education and training (TVET), the paper analyses performance reports at national provincial, district and school level, to determine performance trends after the introduction of Technical Science in South Africa's technical schools. This data is used to argue that the introduction of technical science in South African Technical High Schools has had a positive effect on the performance of learners in the Physical Sciences at Matric levels as well as in facilitating access to TVET colleges. These findings support the view that the introduction of Technical science in the high school curriculum has opened up opportunities for learner access into technical vocational education and training (TVET) thus assisting in meeting the demand for skilled manpower for South Africa's growing industry.

Tanja Mutschler David Buschhüter

Deep structures of student lesson plans at the end of the university teacher education

The ability to plan lessons in the context of structuring is an essential competence of future teachers, which becomes most relevant in school phases such as the practical semester. However, the question of the development of lesson planning skills over practical school phases has not yet been adequately addressed. For this reason, the present study analyzes 126 lesson plans under the aspect of structuring physics lessons and a possible change over the practical semester using a category system for concept building derived from the basis-model-theory. In a two-step procedure, the chain of actions steps are first assigned to the individual actions presented in the lesson plans and then the respective implementation quality is assessed. The analysis of the data reveals that the deep structure of the student lesson plans is principally structured in accordance with the basis-model-theory with regard to the deep structure elements. Nevertheless, clear deficits in the quality of implementation - i.e., the assessment of the extent to which the actions are actually conducive to learning in the sense of the learning objective - become visible. Over the practical semester, no significant change in deep structuring is evident. The paper discusses possible approaches for science teacher education.

Veeshan Narinesingh Farrah Simpson

Mentorship to Combat Loneliness, Bridge Opportunity Gaps, and Fight Underrepresentation in STEM Disciplines

This article describes the structure and benefits of The National Society of Black Physicists and Harlem Gallery of Science Mentoring Program – a culturally relevant, virtual mentoring program for youth from underserved communities. The program was successfully piloted during the COVID-19 pandemic. The goals: combat students' feelings of loneliness, build a community, bridge opportunity gaps, and help address underrepresentation within STEM disciplines. Middle and high school mentees were matched with university student mentors who shared similar interests and racial, ethnic, and sociocultural backgrounds. Mentors and mentees engaged in weekly structured conversations as well as tri-weekly educational and professional development workshops. IPA analysis (Smith, 1996) was applied to transcripts from focus group interviews and program events to identify superordinate and subordinate themes amongst mentee outcomes. Mentees were able to receive numerous benefits from the program. Various superordinate (subordinate) themes were identified: social-emotional support (support with mental health, and family-like bonds and inclusivity), building paths to academic and professional success (demystifying success, and skills for success), and supporting connections to STEM (nurturing interests in STEM, and seeing oneself in STEM careers). The NSBP-HGS mentoring program shows great potential to be continued and replicated beyond the COVID-19 pandemic.

Fredrica Nash

Exploration of Teacher Discursive Claims Enacting Social Justice Pedagogy in 7th grade Science

Science teachers often find themselves deciding between using traditional or reform-based approaches to instruction or a combination of both. However, few consider how they might integrate social justice pedagogy to support the development of learner content mastery and understanding of issues of social justice. This can be attributed to a number of factors. This study explores the discursive claims of a 7th-grade science teacher with strong commitments to social justice and transitional science teaching and learning beliefs. Results from this study demonstrate that social justice pedagogy can occur in the science classroom and is dependent upon the beliefs of the teacher about whether all students can learn, the role of shared ownership in learning, students' sense of belonging, storytelling, and holding students to high expectations. As these themes emerged in the study it can be inferred that social justice pedagogy has a role in supporting students' content mastery and developing their sense of empowerment.

Melissa A. Navarro Terrance Burgess

Challenging dominant science and language ideologies and practices as a 7th grade dual language teacher

This paper set brings together seven emerging scholars and their collaborators together to explore diverse methodological, theoretical, and pedagogical approaches to support justice-oriented STEM education. Five papers will be presented that use different theoretical, methodological, and pedagogical approaches to explore working towards expanded learning opportunities with learners and their

teachers. Additionally, these papers are situated with grade levels and formal/informal learning settings. After the papers are presented, the question of how can diverse research methodologies, pedagogies, and conceptual frameworks unite to support justice-oriented STEM teaching and learning? will be discussed by the presenters as well as the broader audience. The intentionally diverse topics of this paper set will allow the NARST community to engage how multiple approaches are needed to support justice-oriented STEM teaching and learning.

Shannon L. Navy Elena Novak

3D Printing with Preservice Teachers: Implementation, Effects, and Future Directions

Although it is known that 3D printing can be beneficial for student learning, little is known about how preservice teachers learn about 3D printing in teacher preparation programs. To increase the knowledge in this area, this paper focuses on the effects of 3D printing on preservice teachers' efficacy, content knowledge, fascination, innovation, and learning. The participants were 58 early childhood education preservice teachers enrolled in two sections of a science methods course at a university in the United States. The science methods course integrated a 3D printing experience across the semester. The quantitative data for this mixed method study included measures for content knowledge, efficacy, fascination in science, and innovation. The qualitative data included written reflections. Findings revealed the 3D printing project improved the preservice teachers' efficacy, content knowledge, fascination in science, and innovation. However, there were no differences in outcomes for students who completed the project individually compared to students who completed the project in groups. In addition, the preservice teachers reflected on learning about 3D printing technology, 3D printing implementation in classrooms with students, and engineering design processes. This study highlights the importance and benefits of an embedded 3D printing experience for preservice teachers during their preparation program.

Ross H. Nehm Gena C. Sbeglia

The Importance of Family-level Variables to Evolution-related Perspectives and Careers in Black Undergraduates

This study seeks to advance understanding of the factors responsible for the extreme lack of diversity in the field of evolutionary biology (EB). Family-level variables have received little attention in evolution education research, and the relationships between individual and family-level variables relevant to EB degrees and careers in Black/African American (BAA) undergraduates lack exploration altogether. A greater understanding of family-level variables will be central to building a conceptual model that can shed light on the causes of, and solutions to, BAA underrepresentation in EB. We employed Herndon and Hirt's conceptual framework on Black families to structure mixed-methods investigations of the "early college family influences" stage of BAA undergraduates. Quantitative data indicated that family-level variables were significantly and meaningfully associated with many individual-level variables relevant to EB interests and careers. Qualitative data corroborated these findings but also contained many examples of large parental influences in student decision making and student difficulty navigating

evolution-related topics with their families. Family conflict was associated with individual conflict. Family reactions to possible pursuit of an evolution career were associated with evolution career interests. Religiosity had one of the weakest relationships with family reactions to a career or degree in EB.

Ursula Nguyen Catherine Riegle-Crumb

Gender Atypical? Examining the Gender Identities of Women in Engineering

Women remain under-represented in engineering. However, there is limited research on the gender identities of women pursuing gender non-normative fields. Using an intersectional analytic lens, this quantitative study examines the multi-faceted gender identities of a diverse sample of 660 college women studying engineering across the U.S. Specifically, the study investigates how women pursuing a gender atypical field view their gender in terms of gender centrality, female typicality, and male typicality. Results from descriptive analyses reveal that young women in engineering view their gender as generally important to them. Additionally, they express their gender identities as neither fundamentally different from other women nor as more similar to men. Findings from this study point to the importance of utilizing an intersectional lens, such that gender centrality and relationships among gender identity measures vary by women's racialized identities and socioeconomic status. Therefore, this study provides new insights into the heterogeneity surrounding the gender identities of women in male-dominated STEM fields.

Katia Bill Nielsen Ene Ernst Hoppe

Art-based Methods and Signs of Science Capital: Approaching Young Children's Experiences and Relation to Science

Science education are fraught with challenges that call for research to explore the complexity of how people from various backgrounds and at different ages interact, engage with and relate themselves to science. In this paper, we examine a possible approach for the investigation of young children's relation to science and we explore what we might learn by employing the theoretical concept of science capital. Based on a longitudinal qualitative project following children and young people through primary school in Denmark, we argue that art-based methods are valuable in exploring how young children experience and relate to science. We further argue that science capital as an analytical lens has the potential to direct our attention towards inequalities in the resources, with which children enter primary school. Through the presentation, we hope to open up the discussion about how we might approach young children both methodologically and theoretically in order to understand their perspectives and possibilities for participation in science.

Katy Nilsen Christopher J. Harris

Examining Teachers' Attempts to Support Student Motivation in Middle Grades NGSS Classrooms

The Next Generation Science Standards reflect an ambitious vision for science education where students investigate phenomena or solve problems through three-dimensional learning. This type of relevant, authentic science learning can increase access and opportunity for all students. This requires the kind of instruction where students are actively engaged in their learning. Such engagement requires attention to and support for student motivation, but there are very few resources available to teachers to help them in this endeavor. In this study, we examined teachers' attempts to support students' motivation during science instruction. During a summer professional learning experience, teachers learned about instructional strategies organized around five motivation design principles: belonging, confidence, learning orientation, autonomy, and relevance. Over the subsequent school year, they attempted to implement these strategies. We collected and analyzed video data of six teachers' classroom instruction. We categorized instructional actions captured in the video data according to the five principles. Then, we looked across the categorizations to identify and describe patterns in teachers' principle-aligned instructional actions. We highlight evidence showing teachers' differing strategies for supporting student motivation in science class and discuss practical implications for developing curricular supports for teachers.

Pernilla Nilsson

TPACK in teacher education - Supporting pre-service teachers' reflections and use of digital technologies in science teaching

During the last decades, digital technologies have been more and more integrated into teachers' classrooms. As a consequence, there are high demands on teachers' competencies in using technology in their everyday teaching. This paper builds on the growing focus on learning about teaching science with digital technologies, and the relationship between different elements that constitute teacher knowledge and how these are captured and understood during teacher education program. In the paper, research on PCK is used to inform the discussion of TPACK and how student teachers might develop their knowledge of integrating technology into the teaching of a particular science content. Content Representation (CoRe) as a reflective tool is modified to a Technological Content Representation (T-CoRe) to stimulate 24 student teachers' reflections on how they integrate digital technologies into their science teaching. When a CoRe illustrates and contributes to capturing and developing student teachers' PCK, a T-CoRe contributes to stimulate and capture student teachers' reflections on how to integrate digital technologies in their science teaching (i.e. TPACK). As such, the paper attempts to capture how student teachers integrate digital technologies into their science teaching an approach to explore the relationship between PCK and TPACK.

Ryan Nixon Sarah J. Fick

An Exploration of Learning Science Subject Matter Knowledge Through Teaching in a Methods Course

Contemporary reforms in science education emphasize the importance of supporting equitable sensemaking through privileging ways of knowing science that honors students' ideas, experiences, and

community resources. Recognizing the challenge of learning to do this work, this paper set investigates how elementary preservice teachers (PSTs) can learn the knowledge and practices that facilitate more equitable learning opportunities. Paper 1 examines PSTs' engagement in equitable sensemaking of local phenomena as learners and how the PSTs discuss using local resources to engage students in making sense of local problems. Paper 2 focuses on PSTs' subject matter knowledge required for noticing and using students' ideas in equitable ways. Paper 3 examines how PSTs' thinking about how to leverage students' ideas and resources change over the course of a semester. Paper 4 investigates how PSTs noticed opportunities for promoting equitable sensemaking within their enacted lesson plans. By focusing on different elements involved in learning to support equitable sensemaking, this paper set illuminates the complexity of this work, and thus, the multiple dimensions that require consideration in elementary education. The findings have implications for teacher educators and curriculum developers working to prepare teachers to develop the practices and dispositions that move toward more equitable teaching.

Eric Nolan

Moral and Ethical Development through Socioscientific Holistic Perspectives (SSHP)

Although science education settings seek to teach students functional scientific literacy, gaps still remain in addressing the social, political, ethical, and moral contexts of scientifically-based issues. Empirical research presented in this proposal offers science education teachers and researchers perspectivetaking practices within the socioscientific issues (SSI) framework. The case study research in this proposal used qualitative data to show how perspective-taking tools help learners see how they themselves, or others, view an issue through a moral and ethical lens, while thinking critically about the issue's scientific nature. Socioscientific perspective taking (SSPT) is an extension of SSI which guided this presented research in the development of a Four Quadrant-designed curriculum (SSPT-FQ) capable of teaching subjective and objective features of individual and collective perspectives on climate change. Findings demonstrated students' moral and ethical reasoning on the topic of climate change through the SSPT-FQ curriculum. Science teaching and learning can benefit from SSPT-FQ by making content more accessible to a wider range of interpretation and experience. This proposed presentation would benefit NARST members through new curricular and research designs making use of SSPT-FQ since it evokes a sense of inclusion and diversity of perspective while maintaining the essence of evidence-based argumentation.

Noushin Nouri William F McComas

Proposed Teacher Competencies to Support Effective Nature of Science Instruction: A Meta-Synthesis of the Literature

Enhancing students' understanding of aspects of the nature of science (NOS) is an important goal of science instruction. Of course, this can occur only when teachers are adequately prepared for teaching NOS but there remains debate about adequate NOS teacher preparation. Based on a qualitative meta-synthesis of recent research literature, we propose a framework of competencies for what teachers

need to know to be effective NOS instructors. Fifty-eight peer-reviewed journal articles targeting NOS instruction for, and related classroom practices of, preservice and inservice teachers were analyzed. This evaluation resulted in the identification of 20 specific competencies clustered in seven categories deemed necessary in the support of effective NOS instruction, generally divided into those that are NOS specific and those directed at more general pedagogical issues. These include (1) general NOS knowledge, (2) science subject matter knowledge, (3) knowledge of learners with respect to NOS, (4) knowledge about NOS instructional strategies, (5) knowledge about NOS assessment, (6) general pedagogical knowledge, and (7) teachers' motivations and beliefs about teaching NOS. Proposed competencies can be used as a guide for science educators preparing teachers who, in turn, are able to demonstrate NOS competencies and enhance the quality of their students' learning.

Mohammad Nurul-Hassan Sarah El Halwany

Applying an Action-Oriented Pedagogy and STEM Teacher Identity: An Autoethnography

Humanity is facing myriad 'wicked' problems — including those linked to climate, surveillance systems, manufactured foods, habitats and related species diversities — associated with capitalism-influenced fields of science and technology. Assuming capitalist manipulation of public knowledge and subjectivities and learners' diverse abilities, cultural and social capital, etc., the five papers in this Related Paper set provide theoretical and empirically-based evaluations of a constructivism-informed pegagogical schema (ReActions) that prioritizes direct teacher instruction of often difficult-to-discover conceptions in relationships among science and technology and societies and environments and education encouraging and enabling students to independently implement sociopolitical actions to overcome harms like those above of their concern. The five papers appear to support Unity and Inclusion for Global Scientific Literacy through qualitative action research to apply and evaluate the ReActions schema in multiple educational contexts (primary, secondary & tertiary), drawing from Science & Technology Studies [STS]) and the arts to understand possible alignments among numerous 'actants' within a growing dispositif (i.e., purposeful machine-like actor-networks) that may promote ecojustice outcomes, like: communitycentred (vs. individualistic) goals; ecocentric (vs. anthropocentric) worldviews; tempered (vs. continuous) change; and, intrinsic (vs. exchange) values. STS conceptions apparently aiding this work include: sociotechnical imaginaries; dispositifs; phenomena-semiotic relationships; (de-)punctualization; and, governmentality.

Hajira Nusret Saiqa Azam

Inclusive Science Education: Sheltered Instruction for English Language Learner

This report describes how Sara developed her professional knowledge and practices using self-study inquiry while implementing the Sheltered Instruction guided by the SIOP model during her graduate internship. The purpose of this self-study inquiry in the context of Saras graduate internship was to develop her professional knowledge and practices to teach science to culturally and linguistically diverse groups of students in the Literacy Enrichment and Academic Readiness for Newcomers (LEARN) program. She taught science over ten weeks to a diverse group of English language learners in the

LEARN program. She used self-study inquiry to critique the effectiveness of her science teaching and document her professional learning during her internship. Qualitative data was collected using weekly reflection, debriefing meetings, and field notes. Data were analyzed using the MAXQDA software and applying a deductive analysis approach using the SIOP model as an analytical framework. The findings reveal an expansion of her professional knowledge and practices by showing how implementing Sheltered Instruction and adopting SIOP model components guided her science teaching to ELLs and the ways her professional learning was developed. Keywords: Diversity, inclusion, self-study, sheltered Instruction (SI), sheltered Instruction Observation Protocol (SIOP)

David Perl Nussbaum Edit M. Yerushalmi

Using Argumentative Tasks to Promote Out of Field Physics Teachers' Professional Development

This study uses the boundary crossing theoretical framework to investigate the ways that physics teachers from different disciplinary backgrounds participate in argumentative activities. The research focuses on a case-study: a group of three middle-school teachers - one qualified physics teacher and two out of field biology teachers - engaged in an argumentative discussion concerning the phenomenon of bodies falling through air. Findings show that the argumentative activity helped to externalize the existing boundaries between the teachers' different worldviews. We describe the identified boundaries between the teachers and point out the places where learning (or crossing) of those boundaries took place. Findings also demonstrate that learning was a two-way street: the physics teacher also benefitted from the encounter with a different point of view and a different approach to a physical situation.

Ella Ofek-Geva Michal Vinker

The Impact of COVID-19 Lockdown on Parents and Adolescent Children in Relation to Science Learning

With the transition to distance-learning at the beginning of the COVID-19 outbreak, many parents and students found themselves under lockdown, stuck at home. Many parents found themselves taking on additional responsibilities regarding their children's education. However, children don't always interpret their parents' intentions as they intended. This study results reveal and highlight this complex relationship, showing that parents' emphases regarding science learning changed during the first COVID-19 lockdown and in parallel, the relations between these emphases and their adolescent children's goal orientation and self-efficacy toward science learning also changed. In 2019, one year before the COVID-19 lockdown, the children's mastery and performance orientations towards science, and their self-efficacy in science were significantly correlated with their parent's attitudes towards science. In 2020, shortly after the end of the first COVID-19 lockdown, these relations remained significant, but in addition, the parents' emphasis on performance became a significant predictors of the children's mastery and performance became a significant predictors of the children's mastery and performance became a significant predictors of the children's mastery and performance orientations, and their self-efficacy in science. A small increase in the children's performance orientation and self-efficacy in science was seen, and only a small decline in their mastery orientation towards science. These findings are in contrast with what the literature indicates is typical at this age.

Erika Offerdahl Jessie Arneson

An investigation of argumentation task framing on students' use of data in introductory biology

The research on argumentation in science is vast, examining diverse settings, educational levels, and interventions. Students learn best when their ideas are challenged and when they challenge other's ideas. When data is the focus of argumentation, close examination of ideas encourages students to develop relationships among science concepts and practices, strengthening the cognitive pathways by which students draw on that knowledge. Empirical studies of undergraduates in argument-based laboratory courses and controlled, lab-base psychology studies support this assertion. Notably, research conducted in large-lecture undergraduate courses is largely missing. In this study, we examine we explore the effect of task framing (inductive versus deductive) on student learning during an argumentation module implemented in large-lecture introductory biology.

Mercy Ogunsola-Bandele Bamikole O. Ogunleye

Faculty Voices on the Implementation of Science Education Policy in Higher Education-A Case Study

With the various efforts in reviewing the National Policy of Education in Nigeria which envelops the science education policy on higher education, it became paramount to find out the awareness and implementation of these policy statements in the science education classrooms. This research captures voices and views of 58 science faculties spread over 6 universities selected by purposive and convenience sampling method from a population of 174 universities in Nigeria. The sample interacted with the validated instrument put into five categories namely: policy awareness, expectations, students' enrolment, adequacy for effective science education programme and quality assurance. A mixed method approach involving interviews and questionnaires was adopted to establish corroboration of voices to written expressions. From the results, quite a number of factors were found limiting access to quality science education in the classrooms which eventually impedes implementation of the policy. These include inadequacies in: fundamental science researches, special provision for all inclusive science instruction, funding, equipped laboratories, enrolment, periodic monitoring/assessment and government efforts in popularizing science. The paper emphasized the significant roles science educators can play in the formulation and implementation of an all-inclusive science education policy so that counter strategy of oppression such as politics can be tackled.

Mercy Ogunsola-Bandele Dietmar Kennepohl

A Meta-Study of Science Laboratories at a Distance

Abstract There had been various concerns expressed on the increasing difficulties faced in providing hands-on experiences for the science learner at a distance. This is more pronounced during the COVID pandemic and is coupled with conflicting research reports on students' ability to manipulate laboratory equipment after participating in on-line experimentation. Since the importance of the laboratory

practical cannot be ignored in the STEM disciplines, then it should be made accessible and available to all despite the distance from the institution in space and time. To do this, is the need to 'think outside the box' by exploring alternatives to the on-campus laboratory. The current research conducted a metaanalysis of peer-reviewed empirical articles on these alternatives which includes home kits laboratory, virtual labs, and mobile/remote labs. It included 41 selected articles from 12 different countries published in English from 2006 to 2020. Although the review clearly revealed preference for the virtual and remote lab over the traditional, the advantages of the latter cannot be ignored. The method and procedure, results and discussions of the preliminary findings are presented. Key words: meta-analysis, online learning, virtual labs, home-lab kits, remote-controlled labs

Beyza Okan Ebru Kaya

Exploring the Articulation of Nature of Science Ideas in Turkish Middle School Science Textbooks

Reconceptualized Family Resemblance Approach to NOS (RFN) is one of the approaches explaining nature of science (NOS). This study examined the representation of NOS in the Turkish 5th, 6th, 7th, and 8th grade science textbooks. The textbooks were analyzed through content analysis. The coding units were specified as content, activity, and assessment sections of the textbooks. These units were traced based on RFN categories which are the aims and values, scientific practices, methods and methodological rules, scientific knowledge, and social categories of science. The codes were generated and grouped for each category. The results show that the total frequencies of the codes for each science textbook are 196, 545, 284, and 427 respectively. Even though a consistent progression for the NOS ideas was not found throughout the grade levels, "scientific practices", "social certification and dissemination" and "professional activities" are highlighted more in the activity sections in each science textbook. In general, although there are some references to NOS in Turkish science textbooks it can be concluded that the representation of NOS is still insufficient in the whole textbooks and there is a need to integrate each NOS category in a balanced way in each science textbook.

Ozlem Akcil Okan Miray Tekkumru Kisa

Teachers' Instructional Vision and Practices around Promoting Productive Talk in Science Classrooms

To support students' learning, a wide body of research and instructional reforms emphasize students' engagement in productive talk with rigorous thinking in science classrooms. However, despite efforts, productive science talk is not yet prevalent in many classrooms. To gain more insight into the generation of productive talk in science classrooms, we explored a group of science teachers' instructional vision and practices with respect to promoting classroom discourse. Our analysis revealed variations in teachers' instructional visions and quality of instruction in their classrooms. In most cases, there was an alignment between teachers' instructional vision and practices. We observed high-quality instruction in terms of facilitating productive discussions and rigorous students' thinking in the classroom of teachers with sophisticated instructional vision. Low instructional quality is observed in the classrooms of teachers with less articulate instructional visions of productive classroom discussion. We contend that exploring science teachers' instructional vision and their instructional practices together can provide a

powerful lens to identify the areas of improvement for promoting high-quality instruction in many science classrooms. Moreover, working towards the development of a shared vision of instruction by stakeholders and teachers can support the enactment of high-quality science instruction.

Peter A. Okebukola Tunde Owolabi

Further Probe into Culture, Context and Scientific Explanations by Biology Students: An African Case Study

Science is hollow if unable to explain natural phenomena (Einstein, 1954). The importance of explanation is underlined in science curricula all over the world. The goal of this study was to examine how socio-cultural factors impact on Nigerian students' explanation of biological phenomena. Additionally, it seeks to find out how such factors can be harnessed for improving performance of students on tasks requiring explanations in science. The design was a case study implemented in two schools over a 9-month period involving qualitative and quantitative data-gathering techniques. The topics covered were diversity of organisms, Mendelian genetics, ecology, plant and animal physiology, and biotechnology. During the course of the study, a total of 3,924 scripts containing answers to questions demanding explanation of biological phenomena were graded. A random sample of students was interviewed every two weeks to seek in-depth information on why they offered the explanation to the biological phenomenon in their answers. The teachers noted the socio-cultural attributes colouring each explanation. Follow-up reviews by the research team aggregated five socio-cultural attributes of the explanations namely language, habitat, religious orientation, socio-economic status and gender. The study suggests that science teachers should look beyond traditional variables in the quest to explain students' performance.

Adekunle Ibrahim Oladejo Peter A. Okebukola

I am CTCA, and this is my first Attempt in the Physics Class - How Will I perform?

The study is concerned with the persistent underperformance of secondary school students in Nigeria in physics. The study was conducted in two phases. Phase one was a survey of difficult concepts in physics while phase two explored the potency of culturo-techno-contextual approach (CTCA) in breaking the barriers to meaningful learning of refractive indices. A total of 1, 621 SS3 students from Nigeria and Ghana participated in the survey. The second phase employed a mixed-method design (quasi-experimental and interviews) with a total of 205 SS1 students. The control group, taught with lecture method, had 96 students (56 males; 36 females) while the experimental group, taught with CTCA, had 109 students (54 males; 67 females). Both groups had a pretest and posttest using the achievement test in refractive indices, treatment lasted four weeks. Data gathered in the survey were analysed using mean rank analysis and refractive indices was perceived as most difficult to learn. Phase two data were analysed using one-way ancova since intact classes were used. The result obtained showed that the experimental group performed better (mean for experimental=15.49; control 11.97; [F (1, 202) = 64.48; p < .01] than the control group. Implications of the study were highlighted.

Stacy Olitsky

Retaining Underrepresented Minorities in STEM Majors: The Role of Mentoring in the First Year

Given disparities in retention of university STEM majors, there is a need for greater attention to reducing inequities and supporting underrepresented minority (URM) students. Some studies suggest effective mentoring relationships could serve as counterspaces for STEM majors, fostering a sense of belonging and persistence through challenges. This qualitative study focuses on the freshman year of a university program designed to support URM STEM majors, and explores factors that can contribute to mentoring relationships that promote identity and retention. The findings suggest that even across differences in background between professors and students, an emphasis on personal connections, direct discussion of norms, and consideration of diverse identities can lead to solidarity-producing interactions and contribute to students' sense of belonging. In addition, multiple experiences of recognition by mentors can encourage students to become more integrated in STEM departments. For the participants in this study, the STEM fields were still viewed as groups with boundaries, but the mentoring interactions enabled them to position themselves as insiders and seek further connections. Overall, this study suggests the value of a mentoring program in the freshman year, and that is nested within a community of faculty members intent on supporting URM students in STEM.

Joanne K. Olson Syahrul Amin

STEM Professionals in the Classroom and Elementary Teachers' Content Knowledge

Professional development programs that partner STEM professionals and teachers have been emphasized as a way to improve teachers' science content knowledge. However, the impact of partnership programs on teachers' knowledge is understudied, and prior research has shown that discussions of content knowledge between STEM professionals and their teacher partners are rare. This study examined teachers' content knowledge after participating in a 16 week partnership with STEM graduate students. Teachers' content knowledge was assessed via a misconceptions-based science content test as well as the accuracy, developmental appropriateness, and quality of sense-making experiences during science instruction observations. 122 teachers participated in this study, including a control group that taught under typical classroom conditions. Results show significant differences favoring the treatment group on developmental appropriateness of content, and alignment of the content taught to the targeted idea. That said, sense-making experiences were very poor for both groups, and teachers' content knowledge was not significantly changed at the end of the project. The assumption that STEM professionals will engage with content issues and contribute to conceptual change among teachers appears to be flawed. Partnership projects may have a number of other benefits, but improving teachers' content knowledge continues to be challenging.

Daniel Olsson

Niklas M. Gericke

The Effectiveness of Education for Sustainable Development in Promoting Students' Action Competence for Sustainability

This study revisits the seminal question of the effectiveness of education for sustainable development (ESD). Scholarly attention in the past decade has been increasingly directed towards the concept of action competence for sustainability. However, little is still known about the effects of ESD as a teaching approach to help develop students' action competence for sustainability. This study therefore adopts a three-wave longitudinal design, tapping into the development of 760 Swedish upper secondary science and technology students' self-perceived action competence for sustainability as related to their experience of ESD teaching. We can conclude that ESD has effect on the students' action competence for sustainability. Our longitudinal growth models show that it is possible to develop science and technology students' action competence, which is affected by their experience of ESD teaching at their school. Our findings also reveal that such a development process for students takes time and the contribution of longitudinal research in the field of ESD is therefore important.

Franklin U. Onowugbeda Peter A. Okebukola

Reducing Anxiety and Promoting Meaningful Learning of Difficult Biology Concepts: Can CTCA be a Fix?

The problem this study sought to solve stem from the quest for more potent methods of reducing anxiety and promoting meaningful learning of difficult biology concepts. This was achieved in two phases. The first phase – survey, sought to find out concepts in the biology curriculum that students perceive difficult to learn. In the second phase (quasi-experimental), the impact of culturo-techno-contextual approach (CTCA) was explored to reduce anxiety and promote meaningful learning of the most difficult biology concept identified in phase one. Results from the first phase showed that variation and evolution emerged as the most difficult biology concept. With the emergence of the most difficult biology concept, phase two study was initiated. The sample comprised 45 students in the experimental (23 boys, 22 girls) and 43 in the control (22 boys, 21 girls) in senior secondary school 2 (11th grade). Both experimental and control classes were pretested and posttested (after treatment) with the same achievement and anxiety measures. The result showed that Pillai's Trace F = 7.30; p < .05 confirmed the significance of CTCA in reducing anxiety and promoting meaningful learning of variation and evolution.

Jan-Martin Österlein Mathias Ropohl

Investigating The Effects Of Instructional Support On Students' Inquiry-based Writing In Chemistry

In terms of writing in science class, writing to learn and learning to write can be distinguished. While writing to learn approaches use writing as tool for learning, learning to write focusses on the characteristics of scientific language to help students write better scientific texts. However, learning to write is criticized to only have little effects on students' learning and to not be embedded into the inquiry process. This PhD project seeks to address these issues of learning to write by coupling scientific language instruction to scientific inquiry and the related scientific practices to combine benefits of both approaches. Therefore, a coding manual regarding epistemological and language related criteria for lab

reports has been derived from literature. After refinement, the criteria from the coding manual will be used for the development of instructional support measures using different combinations of epistemological support and two types of language related support. The instructional support will be evaluated regarding its effects on the quality of students' lab reports as well as their content-knowledge development. using an experimental pre-post intervention test design.

David C. Owens Dana L. Zeidler

Considering the conceptual role of compassion in socioscientific issues research

The partisan nature of the current political landscape makes it increasingly difficult for individuals with opposing views to find common ground from which to begin considering and resolving socioscientific issues (SSI). However, given that perspectives from Eastern and Western religions, contemporary culture, and evolutionary science all provide support for the employment of compassion by citizens in their everyday lives, compassion has great potential for serving as such a common ground, but remains understudied. In those investigations that have considered compassion in the context of SSI, the construct was often conflated with other similar constructs, and across studies the manner in which compassion was considered varied. Thus, compassion warrants clarity as a construct. Additionally, it is neither clear what role compassion plays or should play in the consideration of SSI, nor what a progression might look like for learners to practice compassion in the context of SSI. In this theoretical paper, we use conceptual analysis to delineate compassion from its component parts, and offer a framework by which SSI can be considered through a lens of compassion.

David C. Owens Antonio P. Gutierrez de Blume

Gamification: Toward the enhancement of self-efficacy in an introductory undergraduate biology laboratory course

Self-efficacy - one's confidence in their capability to successfully perform a task - is predictive of persistence in the sciences. Science fields are often perceived as disproportionately challenging, with the majority of attrition occurring just after introductory coursework, so bolstering science self-efficacy has potential for mitigating this problem. In this quasi-experimental mixed-methods study, we investigated the potential for the inclusion of game design elements (i.e., gamification) to influence undergraduates' (N = 140) self-efficacy in an introductory biology laboratory course. Eight sections of the course were randomly assigned to leaderboard, repeat-testing, leaderboard with repeat-testing, or control conditions. Mixed within-between ANOVA of participants' Self-Efficacy Questionnaire responses indicated that the leaderboard with repeat testing conditions significantly bolstered students' self-efficacy as compared with control and leaderboard conditions, and was the only condition to exhibit positive pre- to post- effects. Thematic analysis of participants' open-ended questionnaire responses identified sources of self-efficacy made salient by the inclusion of game elements. Findings suggest that gamification can be employed to bolster self-efficacy to learn biology, though instructors should take care when selecting which elements to include in learning environments and in what combination, as the gamification effects in this study varied based on the element(s) included.

Ilkem Özdinç Dilara Kara

Pre-service Teachers' Motivations to Participate in the Near-Peer Mentoring Program

Near-Peer Mentoring (NPM) is a program that is carried out by matching the students who are new to the university and in the upper classes (Holbeche, 1996), aiming their academic, emotional, and social development (Zaniewski & Reinholz, 2016). The current study utilizes the Expectancy-Value Theory to investigate the motivations of pre-service teachers to participate in the NPM program as a mentor and to examine the utility and costs they attach to the program (Eccles, 1983). This qualitative inquiry was carried out with a total of twelve mentor participants who were junior and senior pre-service science teachers. The data was collected within the spring semester of the 2020-2021 education year by means of individual interviews via Zoom. The results revealed that the participants found the program useful, benefited from this program in terms of social/emotional support and academic career, and stated that it would be more beneficial if the content of the program was improved. The findings of this study will create an opportunity for the development of NPM programs in universities and for improvement of the content.

Ferah Ozer Nihal Dogan

A novel method for measuring problem-definition progression of middle schoolers: Use of student artifacts 1

The designation of problem definition ability of middle school students is a problematic issue, in terms of the measurement techniques and the methodologies. Thus, the purpose of this study is to propose genuine process-oriented problem-definition measures to measure problem-definition progression and a method for detecting misconceptions of middle school students within contextualized ill-structured problem cases, the use of student artifacts as measurement tools. The participants of the study are n=129 middle school students from two public schools located in a small city of Turkey. The group was exposed to specifically designed modules mainly promotes the development of problem-solving and problem definition skills. The changes on the problem definition abilities were tracked qualitatively through student artifacts within the modules. Novel categorizations were generated according to each interventions' ill-structure problem cases about problem definition ability on a 4-point scale rubric format as: 0: undefined; 1: insufficiently defined; 2: partially defined; 3: scientifically defined. The results showed proposed methodologies' accurateness and contextual alignment in terms of science learning environments and disadvantages of using other types of structured tests were critically discussed. Practitioners are encouraged to use these process-oriented techniques along with specifically generated rubrics to understand the progressive nature and development of those cognitive skills for future studies.

Ferah Ozer Nihal Dogan

A new way to promote creative thinking skills of students: Innovative science learning environments In societal and global contexts of 21st century, individuals are expected to find useful, cost effective solutions for massive problems, such as to build eco-friendly machines or managing a pandemic etc., that would require them to be creative on their solutions. Creativity and creative thinking abilities, now also regarded as the 21st century skills, can be promoted at younger ages with proper facilitation and providing relevant opportunities to students during their schooling years. Thus, our purposes for this study are three-folded: 1-to examine the impact of series of designed innovative science instructional interventions, called as Hybrid-in-CPS approach, on middle school students' creative thinking abilities; 2the contribution to the science education literature by detailed examination of young students' creativity progression, 3-to propose a contemporary hybrid model for designing an innovative science learning environment that promotes the development of creative thinking abilities. Torrance Tests of Creative Thinking (TTCT) scores were used to measure progressive development of n=208 (treatment n=133; controlled n=75) middle school students' creative thinking abilities. As results showed, students on treatment groups outperformed the controlled groups in all aspects of creativity, especially in terms of Fluency, that is generating new ideas is also considered one the most important factors especially for science education.

Ilgim Ozergun Sevil Akaygun

Preservice Science Teachers' Descriptions of Simulation-enhanced Inquiry-based Lesson for Asynchronous Learning Environments

The purpose of this study was to explore how preservice science teachers' descriptions of simulationenhanced inquiry-based lesson for asynchronous learning environments have been affected through SIMINA (Simulation-enhanced Inquiry-based Asynchronous Environment) professional development module. To explore any changes that may have occurred in the descriptions of inquiry-based science education, simulations, and asynchronous learning environments; ten volunteer senior preservice science teachers participated. In this phemenographic qualitative study pre-interviews, post-interviews, and field notes were used as data collection tools. The preliminary findings indicated that in the postdescriptions preservice science teachers rely more on their own teaching and learning experiences related to inquiry-based science education, simulation, and asynchronous learning environments. Regarding the inquiry-based science education, one considerable change was the increased number of codes related to research question and the data. Regarding the simulation, one remarkable change was the revealing of two new categories: resources and aspects. In terms of the asynchronous learning environments, one considerable change was in the communication category. In the pre-descriptions the focus was more on no interaction whereas in post-descriptions focus was more on how to communicate. Consequently, this study might introduce some innovative elements, such as inquirybased science education, simulations, and asynchronous learning environments, to the science education.

Nilay Ozturk Kubra Yolacti-Kizilkaya

Preservice Science Teachers' Informal Reasoning Modes in Two Different Issue Contexts

This study aims to explore preservice science teachers' informal reasoning modes modes in the context of hydraulic fracking and land management issues. The participants were a conveniently selected group of 46 preservice science teachers. In this descriptive study, qualitative data were collected by Open-Ended Questionnaire Assessing Informal Reasoning developed by Wu and Tsai (2007, 2011) and adapted to Turkish language by Ozturk and Yilmaz-Tuzun (2017). Analysis of participant responses to the open ended questionnaire revealed six categories of reasoning modes. More specifically, related to hydraulic fracking issue, PSTs' arguments were categorized as; social-oriented, economy-oriented, ecologyoriented, science and/or technology oriented, risk-oriented, and political-oriented while PSTs' arguments related to land management issue were categorized as; social-oriented, economy-oriented, ecology-oriented, and risk-oriented. For both issues, PSTs mostly generated ecology-oriented arguments. Participants' average number of arguments were 3.54 for hydraulic fracking and 2.93 for land management issue. In addition, participants in average generated 2.54 types of arguments in hydraulic fracking issue, and 1.62 in land management issue. Discussions and implications of the findings for preservice science teacher education were provided.

Emrah Ozyurek

Beyond Excellence In Science Teaching Practice: Virtuosity In Science Teaching And Developing Virtuoso Teachers

Globalization has resulted in rethinking and redefining excellence in science teaching practice. Teachers are no longer a member of local community. They are members of a global community, which requires them to teach beyond local boundaries. Therefore, excellent teaching should contribute significantly to students' intellectual and social learning gains as well as cultivating character virtues like moral, performance, intellectual and civic virtues, which are central to imparting scientific literacy for critical engagement in science education. Therefore, establishing virtuosity, how to become a virtuoso science teacher, that is, an "educational artist" shaping students' understanding of science, improving independent judgement, insightful decision making and pedagogical reasoning, requires consideration in science teacher education. This comparative case study conducted in South Korea, Israel and Turkey investigates virtuosity in teaching, and how virtuoso teachers develop. The study is framed by social constructivist, hermeneutics and critical perspective to understand meaning-making processes in teacher-student relationships and how social interactions are shaped by social and cultural factors. The study took place in two phases: a systematic review to understand how continuous professional development plays an important role in developing virtuoso science teacher; followed by data collection in South Korea, Israel, England and Turkey through interviews and observations.

Greses Pérez Okhee Lee

Amplifying the Voices of Multicompetent students in STEM by Centering Justice and Audience Design in Engineering and Science

This related paper set is a collaboration of scholars and practitioners from different stages in their careers and explores various methodological, theoretical and pedagogical approaches to move towards justice and equity in science and engineering education. The five papers in this proposal focus on creating opportunities for traditionally marginalized voices to contribute their values and practices towards the creation of knowledge and solutions for all. The set addresses the question of how scholars, practitioners, and community members can work together in bringing the wealth of experiences and practices of students and their lived realities into science and engineering. In alignment with the NARST presidential theme, the presented scholarship addresses "issues of racial inequities and social injustices related to science" and engineering. The ideas presented in these papers call on us to cherish and invite the richness of cultural, cognitive, and linguistic resources that Black and Latinx students bring for engagement and learning in science and engineering while staying true to their communities.

Martin F Palermo Angela M. Kelly

Chemistry Teacher Retention, Migration, and Attrition

The chemistry teacher pipeline has experienced the loss of teachers due to turnover. High turnover contributes to localized staffing problems and a revolving door of novice teachers, particularly in the sciences and in urban and rural locales, impacting student achievement. This nonexperimental, longitudinal study examined patterns in teacher turnover (retention, attrition, and migration) of one cohort of chemistry teachers (n=2410) over a five-year period between 2012 and 2017. Of the 2410 teachers, 196 retired from teaching during the five-year period. Descriptive statistics were generated for the remaining 2214 chemistry teachers, 79.4% (n=1757) stayed in their school districts, 11.6% (n=256) left public school teaching (preretirement) and 9.1% (n=201) moved school districts. Of the teachers that migrated to different locales, 61% moved from urban or rural to suburban schools. A multinomial logistic regression model revealed that experience, course load taught in chemistry, certification in chemistry, and teaching in isolation were all predictors of chemistry teacher attrition. Chemistry teacher migration was predicted by experience, chemistry performance, and teaching in isolation. These findings have implications for the preparation and support of chemistry teachers particularly for those teaching in urban and rural locales and those teaching in isolation.

Sahrish S. Panjwani

A Review of Literature on Professional Learning for Science Teachers of Students with Learning Disabilities in the K-12 Setting

This review looks at the literature on professional learning programs targeted for educators working with students with learning disabilities in the science classroom. Individuals with Disabilities Education Act (IDEA) requires students with learning disabilities to be included in the general education setting, given that they are provided with any necessary accommodations. Many different professional learning programs have been conducted that have targeted educators teaching science to students with learning disabilities, and the effectiveness of those can be measured based on teacher learning of the knowledge and skills present and through student learning of the science concepts. Collaboration among science

and special educators was a theme that emerged from a majority of the literature along with the use of inquiry-based lessons with students with learning disabilities and providing educators with direct experience opportunities to practice the knowledge from the professional learning sessions immediately. There was a limited amount of literature available, which indicates that there is still a need in the field for more research on professional learning programs geared towards educators working with students with learning disabilities in the science classroom, and perhaps the professional learning programs themselves.

Byung-Yeol Park Todd Campbell

Science Teachers' Interactions With and Conceptions of Curriculum Use

With recent shifts toward standards-based science teaching and learning internationally, researchers have noted the need for a deeper understanding of how teachers use a curriculum. The purpose of the study is to examine how science teachers interact with curriculum and help better determine what role teachers' conceptions of curriculum play in how they implement curriculum. The authors used the conception of 'curriculum use', which concerns itself with the ways in which a teacher interacts with and is influenced by materials resources constructed to support instruction. Further, the main focus lies on teachers' conception of their role within the teacher-curriculum relationship, where their perceptions might range from that of an enactor of planned curriculum to that of a collaborator with curriculum materials to better understand how their conceptions influence their curriculum use. Three in-service teachers participated in a post-curriculum implementation interview after a professional development workshop. The interviews were analyzed through thematic analysis. In the end, in the context of the implementation of the curriculum, a better understanding of teachers' experiences and interactions with curriculum emerged to inform researchers about how curriculum resource designs can be improved to take advantage of how teachers were found working with curriculum materials.

Wonyong Park Sibel Erduran

"It's a lesson with no answer!": Understanding preservice teachers' lesson development using history of science

While many recent curriculum reform documents worldwide have stressed the value of history of science (HOS) in science teaching, teachers' experience of engaging in the development of history-based science lessons remains an understudied domain. In this exploratory study, we investigate how two groups of preservice science teachers collaboratively developed science lessons using history of science. Undergraduate preservice science teachers (PSTs) in a large university in Korea participated in the study. Over a semester, each participant group developed one science lesson unit based on historical ideas or episodes in science. The research aims are to understand what deliberative issues arose while each group of PSTs developed their lessons, what influenced their curriculum decisions, and what PSTs learned from the development experience. Data sources included questionnaires, interviews, reflective essays, audio-recorded design conversations, and microteaching sessions, and the curriculum materials produced by the PSTs. Focusing on two groups, we discuss several deliberative issues that emerged from

the interfaces of HOS, scientific content knowledge, and pedagogical considerations. The collaborative development process was found to have prompted PSTs' reflection about these issues, which created professional learning opportunities. We discuss the implications for science teacher education and professional development.

Jennifer C. Parrish Jacob Pleasants

Using Card Sort Epistemic Network Analysis to Explore Preservice Teachers' Ideas about the Nature of Engineering

The Next Generation Science Standards place substantial emphasis on engineering as part of science education efforts in the United States. That, in turn, has created an urgent need to understand how to prepare teachers to incorporate engineering into their instruction. A richer understanding of teachers engineering knowledge and how they make connections among engineering and science ideas would help teacher educators design more effective learning experiences. The present study brings the intersection of science and engineering to the forefront, shedding light on preservice elementary teachers' ideas about engineering and how engineering is related to science by using Epistemic Network Analysis (ENA) to explore how and to what extent preservice teachers form connections among a set of engineering and science ideas.

Shira Passentin David L. Fortus

Adolescents' Motivation and Self-Efficacy in Science Face-to-Face Learning Environments vs. in Distance Learning

During the COVID-19 pandemic, teachers were required to shift from face-to-face (F2F) instruction to distance learning (DL). Instructional practices that are effective F2F may not be feasible or effective in DL. A goal of middle school science instruction is to maintain and enhance students' motivation and to boost their science self-efficacy (SSE), two characteristics which have been shown to decline during adolescence. Both motivation and SSE were likely impacted by the shift from F2F to DL. Using surveys and interviews drawing upon both goal orientation theory, social cognitive theory, and the TARGETS framework, we investigated the relations between 8th grade students' motivation and SSE towards science learning, their perceptions of the motivational practices of their science teachers, all in both F2F and DL environments. We identified significant decreases in students' mastery orientation, performance orientation (particularly in their competitiveness) and SSE following the shift from F2F instruction to DL, significant decreases in Autonomy, Task and Time dimensions of teachers' practices, as defined by the TARGETS framework. Both Task and Time had an impact on student motivation and SSE in both learning environments, while changes to teachers' Time-related practices were significantly related to the declines to students' motivation and SSE.

Scott A. Pattison Gina N. Svarovsky
Activity Design Principles that Support Family-Based Engineering Learning in Early Childhood

Introducing young children to STEM is critical for cultivating early interests and understanding that ultimately contribute to broader participation in the STEM fields. Despite the growing body of early STEM research, there are still few studies of engineering education and learning at this age, especially outside the classroom context. To address this need, we conducted a design-based research (DBR) study in partnership with a community-based, family-serving organization to both iteratively develop and improve engineering design activities for families with preschool-age children and advance theory about strategies that support engineering design engagement for parents and children. Across three DBR cycles, 16 English- and Spanish-speaking families with preschool-age children (3 to 5 years) iteratively tested three home-based family engineering activities, providing data through video recordings of families using the activities in their homes and interviews with parents about their experiences. Analysis highlighted three design principles for supporting family-based engineering practices with young children: (1) Include narrative contexts and supports that motivate engagement in engineering practices and user-centered design; (2) Present design challenges that leverage the ways families naturally engage with materials; and (3) Align narrative context, design materials, and design challenges to create an open, accessible, age-appropriate solution space.

Jose M. Pavez

Design of Elementary, Middle School and Secondary Science Methods Courses by Prospective Science Teacher Educators: Contents, Decision Making Process and Challenges

Science methods courses (SMC) are a central piece of science teacher education since they integrate science content and pedagogy. Typically, science teacher educators (STE) define the agenda for these courses. The purpose of this study is to describe the topics considered and identify the challenges of prospective STE (PSTE) when designing SMC, as well as the factors influencing their decision-making process. I conducted a multiple case study with 10 PSTE, who participated in an online consultation. The three cases are the design of the elementary, middle school, and secondary SMC. Participants designed a SMC syllabus, a reflection essay, among others. They participated in a think-aloud interview, oral reflections, and interviews. I conducted a thematic analysis with deductive and emergent coding. Findings show that PSTE generally covered all the PCK dimensions in their syllabi. Common challenges are selecting and sequencing contents. The main factor influencing their decisions were previous SMC syllabi.

Corey A. Payne Kent J. Crippen

Effect of a Year-long Career-forward Chemistry Laboratory Curriculum on Persistence of Students Majoring in Engineering

Persistence is a major issue facing students enrolled in engineering programs, particularly for students from underrepresented ethnic minorities. We developed a career-forward intervention that targets persistence by framing student experiences with content, context and specific skills in engineering. This

curriculum replicates the working experiences of engineers situated within the context of a general chemistry laboratory. The purpose of this study was to use the Mediation Model of Research Experience to build the case for our intervention as an inclusive best practice and to further develop the theory based upon data from a full year. This quasi-experimental field test compared variables of engineering and teamwork self-efficacy, career commitment, and engineering identity by subgroup and across consecutive semesters. High pretest scores for career commitment and engineer self-efficacy along with significant increases with a medium/large effect size in engineering identity and teamwork self-efficacy were documented. These results were consistent for URM and non-URM students. This study demonstrates that a career-forward curriculum has a significant benefit in supporting the psychological processes associated with long-term career commitment. Presentation will include further details on the curriculum design, including examples of learning activities, and its relation to the study's context.

Amanda N. Peel Jacob Kelter

A Design-Based Research Methodology Utilizing Conjecture Mapping to Frame Embedded Co-design Cycles

This is a methodology paper that describes our approach to conducting design-based research (DBR) with conjecture mapping (Sandoval, 2014). In our work, we leverage iterative conjecture mapping to frame embedded design cycles for two audiences: teachers and students. One design cycle focuses on professional development (PD) to support computational thinking (CT) integration and teacher outcomes. During our PD, we work with teachers to iteratively co-design new CT-integrated science and math units for their secondary classrooms. For both teacher- and student-facing design cycles, we use iterative conjecture mapping, which frames each DBR step: design, implementation, evaluation, and revision of the intervention. This methodology has implications for design-based research that connects teacher-facing and student-facing learning experiences. The methodology explicitly supports intervention design, implementation, analysis, and revision within embedded design cycles, one for design supports uptake of curricular reform ideas because through the PD, teachers learn about a new approach, design with the new approach, enact their design, learn to analyze their design, and revise their design.

Tal Peer Shulamit Kapon

Using Making to Transform the Learning of Physics into a Personally Meaningful Experience

While recent attempts have been made to integrate Making into the instruction of STEM disciplines, this integration is not straightforward. This study examined students' engagement in an extended (18 hours) activity that incorporated a Maker-Based challenge into the instruction of advanced-level physics in the 10th grade. We present findings from an ethnographic study that followed three groups of students in this learning environment. The data included videos of authentic working sessions and interviews with the students. The study examined: (1) aspects of personal relevance manifested by students' engagement; and (2) affordances of the Maker approach for facilitating such engagement, from the

students' point of view. The analysis operationalized students' sense of personal relevance in the discourse analysis, as instances of high engagement (Azevedo, 2006). The findings highlight the unique affordances of the incorporation of a Maker-Based Challenge into the instruction of science as a way to foster students' sense of personal relevance.

Ivanna Pengelley Amal Ibourk

Creating an Experience of Belonging Within Science: Exploring Science Identity Development in a Counterspace

The guiding research question for the study is in what ways are the developing science identities of young Black women afforded or constrained through their participation in a program focused on race, gender, and science? This study seeks to examine the science identity development of young Black women in a counterspace, because scholars have documented how counterspaces serve as sites for Black women to develop a sense of belonging as they experience safety from oppressive environments and cultivate networks of support. This study is framed by Black Feminist Thought, which contends that Black women are uniquely positioned to understand the intersectional experiences of contexts shaped by race and gender. Portraiture is the methodology for this inquiry into the sociopolitical experience of science identity development because it is an approach that focuses on the interactions between individuals and their context. Data was collected during an eight-week virtual program for young Black women in high school who expressed interest in science.

Roee Peretz Marina Tal

Fostering Undergraduate STEM Students' and Teachers' Systems Thinking and Modeling Skills via a Food-Related Mini-Course

Since the beginning of the 21st century, the world has been changing faster than ever before in human history. Education must respond nimbly and continuously to the dramatic effects of this accelerating pace. With this in mind, the NGSS has pointed to systems thinking (ST) and modeling as two 21st century skills that education systems should prioritize and nurture to prepare the next generation to exercise science-based independent, creative thinking. We evaluated the effect of studying an online food-related mini-course we developed on undergraduate STEM students and teachers' ST and modeling skills. The research questions related to the effect of learning the online mini-course on the participants' ST and modeling skill levels, and to their perceptions regarding the challenges they faced and the contribution of the mini-course to their ST and modeling skills. The participants, who took the mini-course as part of different courses in a top-tier university, responded to online quizzes, in which they also had to create Object-Process Methodology–OPM ISO 19450 models using OPCloud—a cloud-based modeling environment. The mini-course enhanced participants' ST and modeling skills even for those who were not experienced in exercising these capabilities, but the improvement was higher for participants with background.

Matthew P. Perkins Coppola

The Importance of Enactive Mastery Experiences: Teaching Engineering Self-Efficacy in a Pandemic

In the eight years since the NGSS called on teachers to pursue ways to integrate engineering into the teaching of science, educator preparation programs typically integrate engineering design into assignments within existing science methods courses. Few of these experiences include enactive mastery experiences, which Bandura (1997) proposed to be the most powerful source of self-efficacy. This study examines how the COVID-19 pandemic interrupted the engineering enactive mastery experience embedded within a science methods course for spring 2020 and fall 2020. Pre and post administrations of the Teaching Engineering Self-Efficacy Scale to elementary preservice teachers in spring 2020 showed slight but not significant increases in three of four constructs (ability to engage students while teaching engineering, ability to cope with a wide range of student behaviors while teaching, personal belief in the effect of teaching on student learning of engineering). Increases in these constructs occurred in fall 2020 despite the continued absence of an enactive mastery experience. Despite Bandura's claim, this study presents evidence that, similar to Palmer (2006) and Webb & LoFaro (2021), elementary PST are capable of building a strong teaching engineering self-efficacy from other potential sources, including cognitive pedagogical mastery and simulated modeling

Emily J. Perry Arthur Eisenkraft

Supporting Teacher Leadership Development: Roles, Growth and Research

Leaders of professional development play a key role in the ongoing professional growth and support of in-service teachers. Increasingly these roles are taken on by teachers operating in 'hybrid' roles as classroom teachers and as leaders of their colleagues' and peers' professional learning. The leadership of professional development is complex and remains relatively under-researched, and this is particularly true for teacher leadership of professional development. In this symposium we will share learning from multiple perspectives into teacher leadership of professional development, drawing on research and innovation activities from different local, national and international contexts. We will focus on three key themes: the complex and varied roles of teacher leaders of professional learning; the ways in which teachers build their identities, learn and continue to grow in their roles as leaders of professional learning; and the questions we might ask for, and the ways in which we might carry out, future research into teacher leadership of professional learning. The symposium will be structured around presentations and group discussions, with opportunities for attendees to share their experiences, so that together we generate a rich understanding of teacher leadership of professional learning, developing ideas and opportunities for further research and innovation.

Esther O. Peter Peter A. Okebukola

Exploring the Potency of Culturo-Techno-Contextual Approach on Achievement of Secondary School Students in Computer Networking The intense study of methods that have dominated the science education literature alerts us to the fact that most research have failed to realise that culture and context play significant roles in student learning. The focus of this study is to explore the efficacy of culturo-techno-contextual approach (CTCA) on the achievement of secondary school students in computer networking. The study was conducted in two phases. The first phase was a survey, it had 1,501 senior secondary school computer studies students (male=734, female=767) in Nigeria and Ghana. Computer networking was ranked as one of the most difficult concepts and it was selected for the second phase. The second phase adopted an explanatory sequential mixed method whereby quantitative and qualitative data were gathered. The experimental class had 73 respondents while the control group had 52 respondents of junior secondary school 1 (equivalent of 7th grade) computer studies students in Lagos State, Nigeria. Quantitative data were collected through the networking achievement test with respectable instrument measures. Analysis of Covariance result showed that there is a statistically significant difference in the achievement of students taught networking using CTCA and lecture method, F (1,122) = 86.04; p< .05. Implications of the study were highlighted.

Takeshia Pierre

Good Trouble: Interrogating the Definition of Black Resilience in STEM Education

In recent years, literature devoted to applying resiliency-centered interventions for minoritized populations have been studied within the context of higher education. Naturally, science education and STEM disciplines have also incorporated resiliency within studies geared toward improving the educational experiences for students of color. With the underrepresentation of minoritized populations entering STEM fields, researchers have aimed to identify ways of increasing matriculation by means of targeting early adults who occupy STEM and science education fields. Resiliency has been unearthed as a phenomena used in exploration of strategies that influence successful STEM matriculation and/or persistence among minoritized populations – particularly Black undergraduate students. The purpose of this paper is to identify how resilience has been defined in science education and STEM environments and interrogate whether these definitions should stand. The author invites the larger NARST community to challenge hegemonic norms within science education spaces and work together to elicit change for communities of color.

Ashlyn Pierson Bethany Daniel

Rearticulating Deficit Language Ideologies with Researchers and Teachers in Elementary Science Professional Development

This related paper set responds to calls for re-imagining disciplinary learning in science (Warren et al., 2020) and "broadening participation" in STEM (NSF Includes, 2019). Specifically, the papers in this session will explore practices such as anti-deficit noticing as ways to support equitable science teaching and learning. Deficit ideologies can lead researchers and educators to blame students for perceived deficiencies in school rather than attending to the social structures that limit students' opportunities for

learning (Peck, 2020; Philip, 2011). Anti-deficit noticing (Louie et al., 2021) is a teaching practice that explicitly challenges these deficit ideologies by (1) identifying deficit frames that limit students' opportunities for learning and (2) shifting toward anti-deficit frames that empower minoritized students. While anti-deficit noticing is becoming increasingly prominent in math education (Louie et al., 2021), less is known about how this practice can be supported in science education. In response, this session will offer an illustrative example of anti-deficit noticing in a secondary science classroom, and it will explore anti-deficit approaches to preservice teacher education and in-service teacher professional development.

Daniel Pimentel

Teachers' Conceptions of Phenomena in the Secondary Science Classroom

The Next Generation Science Standards (NGSS) have advanced a vision for science education that requires substantial shifts in teachers' instructional practice, one of which is the use of real-world phenomena to motivate student sensemaking and engagement with science practices. Although materials are being designed to support this approach, science teachers may interpret and implement these materials based on their beliefs and conceptions about the role of phenomena in the science classroom. This study proposes a framework to analyze teachers' conceptions of the role of phenomena in science instruction and uses this framework to understand how ten high school science teachers conceptualize, select, and use phenomena in their science classrooms. Findings indicate that teachers consider a variety of factors when selecting phenomena, such as relationship to students' experiences and interests, relationship to teachers' interests, and connections to curricular concepts. Teachers also described using phenomena in a variety of ways, such as hooks, examples, themes, and events to be explained by students. This work suggests that teachers have a range of conceptions about the use of phenomena in the science classroom and varying degrees of alignment with the vision outlined in the NGSS.

Jacob Pleasants Jennifer C. Parrish

Developing Pre-Service Teachers' Understanding of the Distinctions Between Science and Engineering

With the introduction of the NGSS, science teachers are being tasked with incorporating engineering into their classroom instruction. Classroom engineering activities need not be facsimiles of the work of engineers in the real world, but they do need to accurately reflect engineering in order to provide students with authentic opportunities to develop and use disciplinary practices. Developing and implementing such authentic activities requires that teachers have informed views about the nature of engineering. Of crucial importance is teachers' understanding of how science and engineering are related, yet distinct. This study examines an instructional sequence that was designed to promote teachers' understanding of the nature of engineering, with a focus on the distinctions between science and engineering. The sequence also emphasizes how, in light of that understanding, engineering instruction ought to differ from science instruction. The instructional sequence was used in several methods courses, targeting both pre-service elementary and secondary teachers. Using a convergent

mixed-methods approach, we study changes in pre-service teachers' thinking over the course of the learning sequence. The instructional materials we used in the study will be available for attendees, and we will also highlight unique perspectives offered by different data collection methods.

Julia Plummer Katie Nolan

Social and material resources mediating young children's engagement in spatial sensemaking during summer engineering camp

This study investigated spatial thinking among children and educators during a summer engineering camp. We used a distributed spatial sensemaking framework to identify when and how children use spatial sensemaking practices then considered how those practices engaged children in cognitive spatial processes, shown in prior research to predict future success and participation in science. We used qualitative methods to analyze video from a 5-day engineering camp for preschool children (N=8). Our findings demonstrate how engineering activities provide opportunities for children to engage in spatial thinking. First, our findings suggest that preschool-age children used a range of spatial sensemaking practices (sketching, gesture, object manipulation, and spatial talk). Second, we identified patterns in how children engaged in cognitive spatial processes (Intrinsic-Static, Intrinsic-Dynamic, and Extrinsic-Static) as they used spatial sensemaking practices supported children's spatial thinking. However, while educators played an important role in supporting the children during the spatial sensemaking events, we found little evidence for peer support. While spatialized instruction is largely absent from formal early education curricula, this study provides evidence for the ways engineering-based activities can be used to engage children in distributed spatial sensemaking.

Pascal Pollmeier Sabine Fechner

Preservice science teachers' competences in evidence-based practice – A longitudinal case study

Is the earth flat? Is the coronavirus dangerous? Is there man-made climate change? – All these questions need evidence to be answered. Evidence can be seen as the bottom-line for science. However, evidence is not limited to science – it is important for the whole society as can be seen in many present debates. Therefore, students should build up competences to deal with evidence in school. Teachers must guide students to align discussions and judgements on existing evidence. However, even teachers often lack a fruitful understanding of the nature of evidence (Ledermann, 2007). In this longitudinal case study, an intervention was implemented in a pre-service university course to strengthen their evidence-based competences. The intervention was aligned to existing interventions from the health sector. Interviews and a pre-post questionnaire were used to collect data. As first findings show, there is a need to explicitly thematise the nature of evidence in university courses. Teacher students often do not realise that they are actually dealing with evidence.

Kate Popejoy Thomas Hammond

Advancing Teachers' Geospatial TPACK: Three Universities' Professional Development Initiatives

Classroom use of geographic information software (GIS) and other geospatial tools has been a long-held goal of teacher education. GIS is the standard for spatially referenced data management, but STEM curricula often contain learning experiences that do not match the analytic practices that are critical for success in STEM-based occupations. This project, which encompasses teacher cohorts across four US states, employs a distinctive model of integrated teacher professional development and curriculum development (iPD-CD), in which teachers learn GIS and spatial reasoning skills in curricular contexts and apply them in developing their own geospatially integrated curriculum, implemented coherently during the school year. The following research questions are examined: How did the integrated professional development and curriculum development (iPD-CD) process impact teachers' geospatial technological pedagogical content knowledge (GS-TPACK)? What differences, if any, exist in GS-TPACK outcomes between teachers with prior experience with GIS versus teachers with no prior experience? What factors might explain these differences?

Wardell Anthony Powell

Using Socioscientific Issues to Promote Middle School Students' Evidence-Based Reasoning and Decision-Making on Hydraulic Fracking

This study investigated the implementation of a socioscientific issue curricular unit designed to improve rising middle school students' abilities to think critically about the pros and cons of hydraulic fracturing and engage in evidence-based reasoning on whether the practice should be banned in the Northeastern United States. Forty-three rising middle school students from a summer enrichment program for science, mathematics, reading, and writing operated by a non-profit organization in the northeastern United States participated in this study. The instructional unit exposed the students to information and activities on hydraulic fracturing for five consecutive days (50 minutes each day). The findings from this study showed that through productive socioscientific issues pedagogy, the students used the evidence collected from their investigation to engage in evidence-based reasoning about the cost and benefits of hydraulic fracturing on the public health, economy, and the environment. The students used their understanding of the science and engineering practices to construct valid arguments on whether or not hydraulic fracturing should be allowed in their state. The results further indicate that the use of socioscientific issues as a critical pedagogical strategy can equip students with the skills necessary for them to become better advocates for themselves and their communities.

Burkhard Priemer Sophia Chroszczinsky

Perceiving data as inconsistent with expectations - an important factor for sense-making of experimental results

An empirical study with 125 undergraduate students investigated whether students see an inconsistency between their expectations about two different methods to measure the velocity of a bike and provided empirical evidence. The results show that conflicting evidence remains hidden for many students even though it is obvious for teachers. 45 % of all students reasoned - from a scientific perspective - incorrectly or not clearly. This calls for putting more emphasis on making sure that students identify a conflict or validation between data and expectations, a prerequisite for appropriate justifications. This can be done by addressing basic knowledge about statistics and measurement uncertainties when arguing with evidence in the science classroom.

Kevin J Pugh

Transformative Science Education: A Review of Transformative Experience Theory

One of the goals of science education is to get students to see and experience the world through the lens of science—not just during science class, but in their everyday lives outside of school. To support teachers in accomplishing this goal, my colleagues and I have developed transformative experience theory. Transformative experiences are learning episodes in which students use curricular concepts to see and experience the world in meaningful new ways in their everyday lives. In this conceptual paper, I first review the philosophical grounding used to establish the meaning and significance of a transformative experiences. Then I review and critique the research on (a) individual factors associated with undergoing transformative experiences, (b) outcomes that follow from engagement in transformative experiences, and (c) instructional strategies effective at fostering transformative experiences and how they may be supported in science classrooms. However, the research base is still small and in need of large-scale experimental studies.

Nathan A. Quarderer

Factors that Influence Learners' Climate Literacy and Conceptions of Climate Change

Several studies show that students often lack conceptual knowledge and show multiple misconceptions when explaining climate change (Boyes & Stanisstreet, 1993; Flener-Lovitt, 2014; Shepardson et al., 2011). Hence, it is often argued that science education should focus on conveying sufficient conceptual knowledge about climate change, its causes, consequences, and potential ways of adaptation and mitigation. However, besides scientific content knowledge, decision-making and the intention to act in a climate-friendly manner seem also to be influenced by non-scientific factors such as attitudes and value attribution (Dietz, Dan, & Shwom, 2007). The USGCRP (2009) thus promotes to focus education on climate literacy, which includes specific knowledge about climate change, as well as skills and attitudes relevant to the topic. So far, studies examining the impact of climate literacy on actual decision-making are scarce, and the general picture about other factors that contribute to young learners' conceptions of climate change – including the media, family, peers, but also emotional attachment and risk perception – remains somewhat unclear. In this related paper set, we aim to elaborate how climate literacy can be

modelled and assessed, how it can be promoted through meaningful instruction, and how teacher professional development can contribute to this.

Arif Rachmatullah Eric N. Wiebe

Middle School Teachers' Self-efficacy for Teaching Science in a Computationally Rich Environment: A Mixed-Methods Study

Framed using Bandura's Social Cognitive Theory, this study investigated the development and sources of teachers' self-efficacy for teaching science and CT and looking at whether the two constructs are related to one another. A total of eleven middle school science teachers (seven in-service and four pre-service) participated in a CT-integrated science instruction workshop. They then implemented the curriculum they learned and obtained from the workshop in their classrooms. The teachers took questionnaires on science and CT teaching efficacy beliefs four times: before and after the workshop and before and after they taught. As a follow-up, interviews and writing reflections were collected after they took the instruments. Skillings-Mack and repeated-measures correlation tests were run on the quantitative data, and the qualitative data were analyzed thematically. Results from quantitative analyses revealed a pattern of increasing teachers' self-efficacy for teaching science and CT in a computationally rich environment over the administrations of the instrument. Thematic analysis showed three sources of teachers' self-efficacy: computer programming experience, students' interests, and teaching repetition and field experience. This study calls attention to the importance of providing experience for teachers to teacher education programs.

Arif Rachmatullah Eric N. Wiebe

Building a Computational Model of Food Webs: Impacts on Computational and Systems Thinking Skills

Integral to fostering computational thinking (CT) skills, which are increasingly essential in today's digital era, has been the shift from paper-based modeling activities to computational modeling. Research has indicated that modeling activities can advance students' understanding of a system's mechanism (i.e., systems thinking), such as an ecosystem. The current study examines the comparative impacts of paper-based and computational modeling activities on students' systems thinking and CT skills. A total of 365 seventh-grade students were involved in online modeling activities, spanning over four days, and were assigned purposefully to a paper-based modeling (n = 141) or a computational modeling (n = 224) condition. They took systems-thinking-embedded food web and CT assessments before and after the four activities, in addition to a formative assessment after each activity. Multilevel modeling and repeated-measures correlation tests were used to analyze the students' data. The results revealed significant increases in systems thinking-embedded food web constructs in both conditions. However, the increase of CT skills in the paper-based pictorial/drawing condition was not as significant as the increase in the computational modeling condition. These findings illuminate the benefit of engaging students in computationally rich science activities to advance both systems thinking and CT skills.

Jeffrey D. Radloff Dominick Fantacone

Using event mapping to investigate secondary master teachers' enactment of Naval STEM tasks

Science reform suggests secondary teachers enact multidisciplinary integrated STEM instruction. As such, teachers need the pedagogical knowledge to support student learning via engagement in contextualized, real-world problems. Research suggests that while teachers can learn to integrate STEM effectively, variability exists in STEM instruction across classrooms. While variance may be explained by teachers' classroom adaptations, more work is needed to explore what it looks like to enact STEM instruction. The current study explores secondary master STEM teachers' (>8 years STEM teaching) sense-making with implementing Naval STEM tasks. Participants included two middle and high school STEM teachers who were part of a university-school partnership and developed and implemented a Naval STEM tasks coded for teachers' instructional strategies and triangulated with lesson plans and interview responses. Observations were transformed into event maps, or visual representations of teachers' enactments. Findings revealed variation in teachers' implementations and highlighted their use of discussion and hands-on activities to elicit and support students' STEM ideas. Findings appeared to reflect teachers' STEM knowledge and purposeful attention to planning and provided concrete directions for professional learning and STEM education research.

Jennifer Radoff Chandra Turpen

Supporting macro-ethical reasoning in college students' collaborative design work

Many studies show that college engineering students' sense of ethical and social responsibility decline over the course of their college careers (Cech, 2014; Canny & Bielefeldt, 2015; Schiff et al., 2021). One reason is that many college engineering programs and courses reinforce the social-technical dualism, which treats social and macroethical issues as distinct from the technical work more often associated with "real" engineering design. Some programs, like the Science, Technology and Society (STS) program at [University blinded for review], are attempting to challenge this dualism by supporting the integration of social and technical considerations within students' design work and asking students to grapple with the complex ethical implications of their work. In this paper, we present a preliminary analysis of first-year STS students collaboratively reasoning through a design scenario about a small community store facing challenges due to the Covid-19 pandemic. Using methods of discourse analysis, we examine: (1) How did different conceptualizations of the store influence the ways that certain actors' needs were foregrounded and the ways in which power was modeled within the system, and (2) What prompted shifts in these conceptualizations that enabled more complex macro-ethical considerations within the design work.

Ashelee Rasmussen Charles R. Peterson

Drawing-to-Learn in an Undergraduate Herpetology Course: Drawing as a scientific practice to develop Professional Vision

As students participate in authentic science practices to support science learning they engage in specific ways of understanding and seeing. The development of this way of seeing, or Professional Vision, can be supported by drawing-to-learn where the creation of visual representation through drawing is used as scientific practice to support science learning and development of observation skills. This design-based research study implements a drawing method in an undergraduate herpetology course to understand how engaging in drawing as a scientific practice supports students' development of Professional Vision for herpetology. This research documents and describes how undergraduates' Professional Vision for herpetology was evidenced in student drawings and in think-aloud interviews. This research addresses the links between observation and drawing in real-world learning situations and how to effectively implement drawing in science classrooms.

Ali Raza William R. Penuel

Supporting Science Teachers in Using Student Experience Data to Support More Equitable Participation in Science Classrooms

There is an increasing recognition in the role science has to play in issues of in/equity with respect to opportunities to authentically engage in civic activity from local to global scales. In systems of science education, societal power dynamics and resulting inequities interweave both the challenges of the scientific community and histories of inequity within educational systems more broadly. In this related paper set, we explore findings from a mature research-practice partnership, the Equitable Science Education Research Practice Partnership (ESERPP; pseudonym) project, designed to bring together partners from educational research and practice to promote equity and coherence in science education. Throughout the project, we engage in design-based implementation research to support those engaged in the work of bringing equitable models of teaching and learning into science learning contexts that reflect and extend the vision of equitable teaching and learning in four papers across the ESERPP Project's shared goals to align curriculum, instruction, and assessment through a focus on professional learning through open education resource (OER) development, strategic leadership development, and social organizing across a network of networks.

Carina M. Rebello

A Model for Facilitating Multidisciplinary Justifications in Engineering Design Challenges

There is a growing interest for pedagogical innovations that integrate science learning and engineering design. Design challenges often require learners to make decisions informed by multiple justifications using data and reasoning anchored in different disciplines. A challenge of using engineering design is the "design-science gap" in which design justifications are often based on limited supports rather than on sound scientific or mathematical principles and processes. Integrated STEM (ISTEM) lessons use

engineering design challenges that present a unique opportunity to facilitate learners' argumentation skills. However, there are clear distinctions in argumentation between the disciplines (Bybee, 2011). These distinctions have implications within ISTEM for what data are considered appropriate evidence in each discipline, ways to support construction and evaluation of arguments, and ways to validly and reliably assess arguments when utilizing multiple disciplinary ideas and processes, across multiple dimensions (i.e. product and process) and over time. Another important issue in argumentation is the underspecified nature of evidence itself. Thus, we need to consider how various disciplines or communities of practice understand and implement argumentation (Grooms, Sampson, & Enderle, 2018). In this theoretical paper, we propose a model for using argumentation in engineering design challenges that emphasizes the use of multidisciplinary justifications.

Andrea Reeder Fatma Kaya

Developing and Retaining Mid-Career Science Teachers through a Teacher Leadership Program

Teacher leadership is a career opportunity that strengthens teachers' retention in the classroom by adding to their skills, knowledge, and opportunities. This study examined 15 mid-career science teachers who participated in a professional learning program (PLP) to discover how the experiences supported their development to enhance classroom retention. The project focused on mid-career science teachers because of their vulnerability to attrition due to dissatisfaction with the profession. To explore these teachers' career decision-making and identity development, the Social Cognitive Career Theory and Communities of Practice frameworks were integrated to follow their trajectory from the PLP to their schools. Data was collected through interviews and analyzed through first and second cycle coding strategies (Saldaña, 2015). Teachers in the PLP developed a career interest and an identity of a teacher leader through a sense of belonging and enhanced self-efficacy while engaging in collaborative activities. They enacted teacher leadership in their school community and refined their identity by using artifacts from the PLP. The PLP fostered classroom retention by allowing them to make a difference in their school community by being a resource. This study identifies experiences in PLPs that influence the actions, knowledge, and retention of teacher leaders.

Emma J. Refvem M. Gail Jones

An Expanded Understanding of the Influence of Antecedent Socialization on the Choice to Become a Science Teacher

This study explored experiences that contribute to science teacher career aspirations. Researchers have investigated factors that motivate teachers generally, but there are very few studies that examine these factors for science teachers. In this study, 160 pre- and in-service secondary science teachers were surveyed, and a subsample (N=10) were interviewed about experiences and factors that contributed to their decision to select science teaching as a career and the influence of individuals on their career choice. The analyses of the survey and interviews found that teachers reported that their prior experiences as a student in science were influential in their career choice. Further, the teachers reported that having teaching- and leadership-related experiences in informal science settings such as

being a teaching assistant or tutor and volunteering at a museum were significantly more influential in shaping career aspirations than participating in precollege student experiences such as attending a science camp or being in a science club. The implications for teacher education recruitment are discussed.

Melissa Rego Ashley Iveland

Influences on NGSS Instruction: Curriculum, Professional Learning, and District Support

The Next Generation Science Standards requires instruction to go beyond students learning science concepts to engaging them in science practices. Such a shift in how science is taught inevitably impacts other areas of the education system. This study examines the potential role that district support, professional learning, and curriculum play in NGSS implementation, in particular the uptake of an NGSS-aligned curriculum: the Comprehensive Middle School Science Curriculum (CMSSC). Our study was conducted in the context of a larger randomized control trial of the CMSSC.We report findings from 56 seventh grade science classrooms with over 5,700 students across 29 schools in four districts. We examined science instruction, and asked teachers to report on their district, school, and professional learning supports. We found potential impacts on NGSS instruction related to our three areas of influence, particularly around curriculum. Findings indicate that there were significant differences between teachers with and without CMSSC on how often students engaged in five of the Science and Engineering Practices which may relate to features of the curriculum. Further, we found that access to such a comprehensive curriculum was perceived as a valuable asset for teachers and it may have changed how they collaborated with colleagues.

Emily Reigh Daniel Pimentel

Putting on a 'skeptic hat': Teachers' and students' conceptions of critiquing socioscientific data infographics

With scientific disinformation on the rise, students need to be prepared critically evaluate scientific claims in media. Although the NGSS call for students to engage in critique and to evaluate information, little is known about how students engage in these practices with the types of data infographics that are common in social and traditional media. In this exploratory interview study, we examine how students critique representations of data about socioscientific issues and the extent to which teachers provide opportunities for this type of activity in their science instruction. Our findings show that students are able to effectively critique both the source of the data and the design of the study through which the data was collected. Furthermore, we found that teachers value this practice but perceive numerous barriers to its implementation in the classroom. We draw implications for enactment of the standards and development of curriculum and instructional strategies about data. We conclude by discussing how engaging students in the critique of data representations can foster deeper understanding of scientific processes and therefore combat disinformation and mistrust in science.

Kathryn Rende M. Gail Jones

Perpetuation of privilege: Impacts of low pay on workforce equity and diversity in informal education

At the height of the Great Recession in 2008, museum educators were in a state of crisis. Museums were taking financial hits as a result of the economic downturn and educators were losing their jobs in numbers far greater than any other group of museum staff. Now, over a decade later and in the midst of the COVID-19 pandemic, museums are once again experiencing unprecedented closures and staff reductions, all while grappling with the additional role of confronting systemic racism. Exacerbated by the intersection of these crises, issues of educator recognition and valuation are returning to the spotlight as major concerns in the field. This exploratory study examined informal science educators' perspectives on workforce equity, diversity, and professionalization. Through a nationwide survey and selective interviews, educators (n = 132) were asked about their personal and professional challenges faced before and during the COVID-19 pandemic. Results show that 59% of informal science educators surveyed were considering academic or career changes, citing workplace practices and cultures that perpetuate overwork and underpay and that have contributed to the marginalization of educators who have been historically excluded from working in the field.

Matt Reynolds Soonhye Park

Catalyst or Catastrophe: Examining the Influence of the edTPA on Preservice Science Teachers' PCK Development

In the past decade, teacher performance assessments have gained popularity as both formative and summative assessment instruments in teacher education and as a requirement for initial teaching licensure. The purpose of this longitudinal qualitative study was to investigate the potential influence of the edTPA, the most widely implemented TPA in the United States, on preservice science teachers' pedagogical content knowledge (PCK) and PCK development. Through analysis using the constant comparative method, five aspects of how the edTPA portfolio creation process influenced preservice science teachers' (PSTs) instructional practices and PCK development were identified. The edTPA portfolio creation process facilitated PSTs to: (1) increase reflection on their teaching practice; (2) increased integration between components of their PCK; (3) expanded their knowledge of students' understanding and more frequently integrate it into their PCK; (4) more frequently implement student-centered instruction; and finally, (5) develop and more frequently integrate their knowledge of assessment into their PCK. During the investigation, several indirect influences, both potentially positive and negative, of the edTPA on PCK development were identified. Implications for teacher education and directions for future research are discussed.

Abby Rhinehart Deb L. Morrison

Design Principles, Change Theory, and Infrastructuring Needs for Implementation

There is an increasing recognition in the role science has to play in issues of in/equity with respect to opportunities to authentically engage in civic activity from local to global scales. In systems of science education, societal power dynamics and resulting inequities interweave both the challenges of the scientific community and histories of inequity within educational systems more broadly. In this related paper set, we explore findings from a mature research-practice partnership, the Equitable Science Education Research Practice Partnership (ESERPP; pseudonym) project, designed to bring together partners from educational research and practice to promote equity and coherence in science education. Throughout the project, we engage in design-based implementation research to support those engaged in the work of bringing equitable models of teaching and learning into science learning contexts that reflect and extend the vision of equitable teaching and learning in four papers across the ESERPP Project's shared goals to align curriculum, instruction, and assessment through a focus on professional learning through open education resource (OER) development, strategic leadership development, and social organizing across a network of networks.

Jennifer Richards Olivia D. Masse

Experienced Teachers' Thinking about NGSS Classroom Assessment: Resources, Coherences with Instruction, and Shifts through Co-Design

A growing consensus in the field positions the development and use of high-quality three-dimensional (3D) performance assessments as essential to implementing a coherent vision of instruction and assessment that supports meaningful 3D science learning. While there are currently rich opportunities for teachers to engage with and contribute to understandings of instruction aligned with the vision depicted in the Framework for K-12 Science Education and the Next Generation Science Standards (NGSS), studies are just beginning to explore teachers' thinking on and work with NGSS-aligned assessments. In this study, we contribute a qualitative cross-case analysis of three experienced NGSS teachers' thinking about NGSS-aligned classroom assessments, including resonances and distinctions between NGSS instruction and assessment. We also examine how their thinking shifted through participating in a professional learning opportunity that involved co-designing instructionally-embedded 3D performance assessments. Study findings contribute to the field's knowledge base by providing insights into experienced NGSS teachers' thinking about new ways of assessing student learning and coherences between assessment and instruction in the era of NGSS.

Zachary Richards Angela M. Kelly

Predictors of Community College Astronomy Performance

The present study examined the predictive value of academic and demographic variables with respect to the astronomy performance of community college students. Data for this study were collected from a large two-year public community college in suburban New York State. The framework was Bahr's theoretical deconstructive approach to understanding the academic pathways and outcomes of community college students, which examines specific junctures in course taking to identify roadblocks

for progression towards academic goals. Four-year longitudinal transcript data (N=5,842) were explored for the 2015-16 cohort, following them through the 2019-20 academic year; complete data were obtained for n=292 students who enrolled in astronomy. Multiple linear regression indicated significant predictors of astronomy performance included enrollment in developmental mathematics, repeating mathematics coursework, and the number of astronomy courses taken. Demographic variables were not significant predictors, including socioeconomic status, gender, ethnicity, and student age. The findings of this study may inform interventions to improve performance in STEM courses that require mathematical skills in addition to improving overall STEM persistence for both STEM and non-STEM students. Policy reforms may focus on precollege college-preparatory mathematics and community college developmental mathematics programs to improve mathematical skills and conceptual understanding.

Gail Richmond Roberta Hunter

Understanding Informal Science Educator Identity as Critical Leverage for Science Teaching & Learning Partnerships

In the U.S. recent widespread adoption of the Next Generation Science Standards (NGSS) has required deeper knowledge and different instructional practices from all teachers. The ability to take up NGSS-aligned practices is particularly challenging in under-resourced urban school contexts. Our work has centered on developing sustainable partnerships between teachers and informal science educators (ISErs) to support deeper understanding of how to provide outdoor experiences which are NGSS-aligned and teaching that is specific to their place and the cultural and social needs of their students, making use of several frameworks, including place-based, design-based implementation research, culturally responsive teaching and heads-on, hands-on, hearts-on (3H). In this related paper set, we consider the work ISErs do with other educators, students, and the general public, and how these contribute to their identity (Paper1); evaluate theoretical frameworks as interpretive lenses on such partnerships (Paper2); address how we made use of a virtual environment to establish professional community and "set the stage" for summer and school-year learning (Paper3); investigate the program's impact on teachers questioning and subsequent planning intentions (Paper4); address how specific contextual factors shaped the ways the program was taken up and our leveraging of these factors to support participant learning (Paper5).

Alexis Riley Felicia Moore Mensah

Black women science teachers and anti-racist teaching: An argument for Historically Relevant Science Pedagogy

Marginalized communities cannot and do not have decontextualized experiences with how socioscientific issues, such as exposure to COVID-19 as frontline, essential workers, high Black infant mortality rates, air pollution leading to respiratory problems, and other issues, affect their community. As K-12 science teachers and teacher educators strive to dismantle oppressive practices in their classrooms and curriculum, it would be helpful to learn from Black women science teachers who have been engaging in anti-racist practices before the political uprisings of Summer 2020. In this study, three different virtual focus groups, which I call sista circles, were conducted with a total of 18 Black women secondary science teachers. These sista circles had a wide range of experience, ranging from 1 to 22 years of experience across the country and including international participants in Canada and Qatar. Black women science teachers enact antiracist science teaching through: Bringing something new to the community; Using NGSS standards within the context of the community; Teaching at the intersection of history, culture and science; Building critical consciousness in the science classroom. When considering how science teaching and learning can be used within culture-based models, I offer the term 'historically relevant science pedagogy' as an anti-racist framework.

Ronald W Rinehart Mason Kuhn

The Role of Responsibilist Intellectual Virtues in Science Learning

The aim of this study was to examine the interaction between epistemic responsibilism and science achievement in 4th grade students. In this paper we propose that epistemic responsibilism is an underexamined element of epistemic cognition and we seek to add a new theoretical consideration that is grounded in the work of epistemiologists and deployed in the classroom settings described in this paper. Understanding the role that epistemic cognition plays in scientific reasoning has been noted as an integral part of the "three-part harmony" whereby the science teacher seeks to balance conceptual, epistemic, and social learning goals (Duschl, 2008). In this study we contrasted the science achievement of 4th grade students in eight classrooms. All eight teachers used lessons that are commensurate with the aims and processes of the NGSS, and a subset of four of those teachers took additional steps to explicitly discuss and make use of responsibilist virtues in addition to the reliabilist oriented processes of the NGSS.

Julie Robinson Pauline W. U. Chinn

Indigenizing the Processes of Science and Engineering: Increasing Inclusivity with Implementation of the SEP's

The integration of the Science and Engineering Practices (SEP's) in the Next Generation Science Standards (NGSS Lead States, 2013) asserts that students must engage with the processes of scientific investigation and engineering design by applying their understandings and knowledge as integral parts of these processes. However, teachers often lacking sufficient professional development to effectively incorporate the SEP's into their classroom instruction (Kang, McCarthy, & Donovan, 2019). Of further concern is a decontextualized approach to the practices, with models of scientific investigation and engineering design presented as acultural processes that do not embed cultural knowledge and epistemologies (Bang & Medin, 2010). Thus, an approach to science and engineering processes that is grounded in culturally relevant pedagogy and Indigenous ways of learning and knowing is crucial to increasing students' engagement and future participation in STEM. To further this aim, teachers must be sufficiently prepared to Indigenize their integration of science and engineering practices and processes. Presentations in this symposium will highlight methods and outcomes of projects being conducted across diverse communities and regions that are aimed at both fostering Indigeneity in the science and engineering practices as well as supporting teachers with integrating these approaches into their classrooms.

Marc Rodemer Marlit A. Lindner

An Eye-Tracking Study On Learning Representations In Organic Chemistry With Dynamic Signals In Instructional Videos

Instructional videos are frequently used in education. However, there is lacking empirical evidence how to best support students in processing videos that contain spoken explanations with complex representations. In this eye-tracking experiment, static signals (i.e., permanent colored highlighting) and dynamic signals (i.e., sequential highlighting) and a control condition are compared. Eye movements from 28 undergraduate chemistry students were tracked while they were watching instructional videos about chemical reactions in the three different signaling conditions. Students' intrinsic, extraneous, and germane cognitive load, as well as retention were assessed. Data shows that dynamic signals helped students to better focus their attention to the relevant features of the representations (i.e., more fixations on relevant areas). Furthermore, dynamic signals, as compared to static and no signals, increased retention scores as well as germane cognitive load while they decreased extraneous cognitive load. Intrinsic cognitive load remained unaffected across signaling conditions. Overall, the findings show the crucial role of multimedia principles in instructional videos to help students navigate through complex symbolic representations, and improve their learning success.

Miguel Rodriguez Ramon Barthelemy

Cultural and Racial Barriers for International Students of Color in STEM Graduate Programs

Race continues to play a major role in the experiences of students of color at predominantly white institutions. International students are often also people of color making them susceptible to discrimination from faculty, peers, and students. Besides potential racial barriers, international students also experience cultural barriers when engaging with domestic peers. International students have increasingly become an important student demographic making up a large percentage of graduate students in STEM. In this study we interviewed and examine the experiences of twenty two international graduate STEM students of color. To understand their racialized and culturalized experiences, we will use the lens of Critical Race Theory (CRT) and Intersectionality. CRT has deep roots in legal studies and was created for understanding and transforming the relationship between race, racism, and power, thus providing a theoretical framework for analyzing student interviews. Our participants reported experiencing cultural barriers, isolation and segregation, and microaggressions while pursuing their graduate degrees. This article serves to highlight the voices of international students of color while simultaneously raising awareness to the cultural and racial issues that they may face at predominantly white institutions.

Marissa S. Rollnick Stephen A. Malcolm

THE TOPIC SPECIFIC PCK OF VIDEOS ON THE BIG IDEA, "WHAT IS CHEMICAL EQUILIBRIUM"

Due to the necessities of online learning, largely necessitated by the Covid-19 pandemic, teachers are increasingly using readily available online teaching videos as an integral part of their teaching. The videos are freely available but vary vastly in quality. This paper used the construct of Topic Specific Pedagogical content knowledge (TSPCK) to analyse the quality of knowledge for transformation of content knowledge visible in videos on the topic of chemical equilibrium. Twelve videos were sourced from the internet were qualitatively and quantitatively analysis using a rubric. The videos were ranked and three stood out as better than the rest. Preliminary findings indicate that certain TSPCK components are more visible than others. Surprisingly a minority of the videos use sub-microscopic representations, and the difficulty of concepts seem to lack discussion in the videos.

Drew Jason Rosen Angela M. Kelly

Student Participation and Self-Efficacy in Communities of Practice in Remote Undergraduate Physics Laboratories

While laboratory practices have traditionally been conducted in-person, online laboratory learning has been growing in popularity due to increasing enrollments and the recent global pandemic, creating opportunities for accessibility. Because of the virtual nature of the learning environment, students have more autonomy to choose how they participate in their laboratory class. Communities of practice and self-efficacy can provide insights into their participation choices. In this quantitative study, students in an introductory physics laboratory (N=272) were surveyed about their social learning perspectives and their physics laboratory self-efficacy. Three groups of students were identified based upon their self-reported participation level: (1) contributors, who communicated with peers via social media and posted comments; (2) lurkers, who read discussions on social media without posting comments; and (3) outsiders, who neither read nor posted comments to peer discussions. Analysis of variance with post hoc Tukey tests showed significant differences in social learning perspectives between all groups, with a large effect size, and differences between contributors and lurkers self-efficacy, with a small effect size. These findings showcase how online laboratory students may actively participate through lurking. Instructors should consider lurking in an online science laboratory as a legitimate form of participation and engagement.

Veronika Rozhenkova Lauren Snow

Limited or Complete? Conceptions of Teaching and Learning for STEM Teaching vs. Research Faculty

When entering an educational context, instructors manifest certain perceptions of teaching and learning and accordingly implement different teaching methods, which impact students' learning. Previous studies developed a hierarchy of teaching conceptions that range from limited (transmitting knowledge) to complete levels (helping students become independent learners). Using the case of one STEM department at a research-intensive, minority serving institution, we explored the faculty's conceptions of teaching and learning, as well as uncovered their perspectives on the intradepartmental interactions related to teaching. The study participants were drawn from both teaching-focused (Professors of Teaching, PoTs) and traditional research (Research Professors) tenure-track faculty lines. We found that both PoTs' and Research Professors' conceptions fell between the limited and complete levels. The interviewed PoTs, however, were more homogeneous in their views. Furthermore, PoTs perceived their influence in relation to teaching on Research Professors to be marginal while Research Professors spoke positively about PoTs' expertise and the influence they had on their instructional practices. This work suggests formalizing the interaction between these faculty groups in order to promote more sophisticated beliefs about teaching for Research Professors. Additionally, we discuss possible opportunities for PoTs to act as the agents of change within their departments towards this goal.

Simone Rueckert Helena Van Vorst

Challenges with Inclusive Teaching at Vocational Schools in Germany

At German vocational schools, a large variety of courses of education with different – mostly job-related – qualifications can be attended, leading to a significant heterogeneity among students (Euler & Severing, 2014). Facing the challenges of demographic change and a lack of skilled workers, it is doubly important to integrate as many young people as possible into the labor market and thus strive for an absolute accessibility of the education system, especially concerning vocational education and training (Heinrichs & Reinke, 2019). This project combines different perspectives of involved parties in the vocational school sector and aims to shed light on the issue of inclusion in the context of vocational education and training which has been neglected in the past. This will be achieved through uncovering inclusion-related needs at vocational schools and analyzing as well as comparing pre-service teachers' planning and conducting competences for inclusive lessons. Preliminary results show that prospective teachers of all experience levels incorporate elements for increased accessibility into their lesson planning. Most frequently, they integrated methods of recruiting students' interest through relevant and authentic lesson content.

Kathryn Rupp Karyn Higgs

Scaffolding Scientific Argumentation in a Science Inquiry Unit

Evaluating and using evidence to support a claim and providing reasoning to demonstrate why the evidence supports a claim can be a challenging practice for students to learn. In the context of an inquiry task across a science unit, we tested an evidence-sorter tool that helps students to organize and reason with evidence to support their selected claim in a unit culminating argument essay. We found that the number of evidence-reasoning pairings that students provided on their evidence-sorter tool significantly positively predicted the number of evidence-reasoning pairs in the final essay. These results suggest that helping students make more evidence-reasoning connections in the evidence-sorter tool should lead to an increased use of reasoning in the final essay.

John R. Ruppert Jennifer Ayala

Toward a community of civic practice: a case study on service-based experiential learning in support of community driven science engagement

We present a case study of 8 students that emerged from a larger design-based research project seeking to support integration between the STEM programs at a Hispanic Serving Institution (HSI) and the surrounding, traditionally underserved community. The focus of study is a paid, credit-bearing and service-based experiential program that enlists students reflecting the demographics of the surrounding community, in the role of information analysts and communicators. Students featured in this case study worked as a cohort with the community and public health leaders/experts to develop health resources to drive engagement during the COVID-19 pandemic. Data sources for this case study included student interviews, digital daily logs, and final essays, each focusing on the potential personal, professional and community transformation experienced. Our analysis of the data yielded four themes including: (a) considering the role of place and context in science application, (b) navigating the intersection between Nature of Science (NOS) and politics, (c) forging larger communities of civic practice, (d) deepening student agency. These themes align with a growing body of research in Science Education centered on science engagement and also highlight areas where support is needed in student development in experiential, service-based learning.

Tatiane Russo-Tait Catherine Riegle-Crumb

Examining Exclusionary and Inclusionary College Classroom Experiences: Effects on Women in Engineering Majors by Race/Ethnicity

In this quantitative study, we examined the college classroom experiences of a diverse sample of approximately 300 women in engineering college majors across the United States. We measured experiences that were distinctly exclusionary or inclusionary, and explored how these experiences predicted positive engineering attitudes and doubts about staying in the major. Black and Latinx women reported experiencing the least inclusionary climate, while Asian women reported the fewest exclusionary experiences. Both types of experiences predicted similar outcomes across groups, with one exception. While Asian women were the least likely to experience exclusion, it nevertheless was associated with a higher frequency of thinking about leaving the major compared to other groups. This work confirms that women from racially minoritized backgrounds are the least likely to feel included in engineering classrooms. It also problematizes the norm of examining White and Asian women's experiences in the aggregate by assuming these groups hold similar experiences in STEM. This speaks to the need for scholars and educators to consider the heterogeneity of intersectional experiences that women from different race/ethnicities have within engineering classrooms, and the consequences for views of the field and decisions to remain in the major.

Laura Sührig Katja Hartig

Questionnaire Measuring Teachers' Perception of Practical Work in Inclusive Physics Lessons

Practical work is a central element of physics lessons and offers great opportunities to create positive learning environments, particularly when teaching in inclusive learning groups (Baumann et al., 2018). Since the success of inclusive teaching depends to a great extent on the commitment of teachers (Boer, 2012), their views on practical work are extremely relevant to improving practice. In our study we developed and tested a questionnaire for teachers' perception of practical work in inclusive physics lessons. The results are presented on the poster. Baumann, T., Kieserling, M., Struckholt, S., & Melle, I. (2018). Verbrennungen—Eine Unterrichtseinheit für inklusiven Unterricht. CHEMKON, 25(4), 160–170. https://doi.org/10.1002/ckon.201800016 Boer, A. A. de. (2012). Inclusion: A question of attitudes?: A study on those directly involved in the primary education of students with special educational needs and their social participation. Stichting Kinderstudies.

Rolf Saarna Anne Laius

A systematic literature review: assessing sustainability literacy

A small number of articles in the field of education for sustainable development (ESD) reflect on sustainability literacy as the main aim of ESD, although often with varying viewpoints on different dimensions of sustainable development. Nevertheless, researchers have begun to focus on 3 to 4 dimensions of SD: economic, social/cultural and environmental dimensions. The main aim of this theoretical article is to get an overview of academic literature about assessing sustainability literacy, composed on the basis of systematically analysed articles. This theoretical overview enables to create a reliable and valid instrument for assessing sustainability literacy of students at upper secondary school level. Based on the literature, there are two approaches to assess sustainability literacy. One is to use previous research instruments and to modify them. Second method is to implement a public free test on sustainability. All the research articles were engaged in higher education level, among undergraduates, faculty members and staff members. None on the research was done among upper secondary students.

Troy D Sadler Li Ke

Teacher Learning Through Collaborative Curriculum Design During the COVID-19 Pandemic

COVID-19 has impacted nearly every aspect of life in the US and across the globe. This pandemic presents an example of why scientific literacy, conceptualized broadly to include science concepts, the nature of scientific evidence, and ideas about how science works, is so critical. We contend that it is essential for the spaces of science teaching and learning to be spaces in which complex issues like the COVID pandemic are explored. We contend that the science education community has a key role to play in supporting expanding dialogues and learning about critical societal issues particularly those, like the COVID crisis, which are so critically connected with science. This paper set features work from five research teams which took up the challenge of responding to the pandemic through science education. The researchers come together here to share some of the ways in which science education has been leveraged in the midst of the COVID crisis. The goal of the session is to surface what the science education community has learned through the current crisis, critical research directions that are

needed, and how the community can position itself for effectively responding to the next global crisis that will inevitably emerge.

Mounir R. Saleh Bashirah Ibrahim

Attitudes of Preservice Elementary Science Teachers toward iSTEM Teaching: The Role of Adaptive Expertise

Lately, the call for implementation of integrated Science, Technology, Engineering, and Mathematics (iSTEM) teaching has been on the rise. This teaching approach develops innovative skills for students and helps them meet 21st century challenges. However, teachers need to possess positive attitudes toward iSTEM teaching in order to implement it. Therefore, studying factors that influence these attitudes is important. Only few factors have been investigated so far. One putative factor is adaptive expertise. Adaptive experts tend to demonstrate positive attitudes toward unfamiliar tasks. We used a cross-sectional survey method to study the relationship between adaptive expertise in science teaching and attitudes toward iSTEM teaching of fourth year preservice elementary science teachers at a public teachers college. Analysis of responses demonstrated that adaptive expertise in science teaching was associated with higher attitudes toward iSTEM teaching. This finding has promising implications for teacher preparation programs and adaptive expertise researchers.

Sara L. Salisbury Fonya Crockett Scott

Exploring the Potential for Place-Based Ecology Lessons in Middle School Science Classes

Though ecology is a critical subject for children to learn about, the nature of the field of ecology (e.g., interdisciplinary, field-based, variable, and contextualized) makes it difficult for educators to address in increasingly standardized and time-limited k-12 science classes. To help address current issues in the implementation of ecology education in k-12 science classes, as well as explore how various contexts can support students in learning about ecology topics and practices, our preliminary design-based research project explores the outcomes of a carefully designed, weeklong ecology lesson. Our instructional design integrated both place-based education and science-as-practice perspectives, and sought to contribute to students' developing ecological knowledge embedded in their local schoolyard (i.e., place knowledge). Our findings suggest that students' place knowledge grew more complex by the end of the activity, and shifted from more human-centric to place-centric perspectives. We noted that mechanisms of change in this context included students encountering new-to-them species, and reflecting on the variation in species diversity across the schoolyard. As such, place-based education is a powerful pedagogical tool for teaching and learning ecology when educators use local and familiar ecosystems and draw students' attention to easily observed, yet carefully selected, phenomena (e.g., variation, novelty).

Sara Salloum Justina A. Ogodo

The intersections of 'displacement' and science education: Perspectives across international contexts

The imposed reality of the COVID-19 pandemic with its sudden disruption of learners' educational experiences has further amplified societal and educational inequities, especially when it comes to science education (Verma, Campbell, Melville & Park, 2020). Yet, disrupted and interrupted education are a reality for increasing numbers of learners 'displaced' around the world due to war, mass migration, annexation of land (e.g., indigenous people), and extreme weather. This group of learners faces compounded difficulties, and so do their teachers who encounter various pedagogical dilemmas around how to best serve and meet their learning and socioemotional needs. Considering that science is a way to see and understand our place in the world, the intersections of 'displacement' and science education is a topic that deserves attention. This equity and ethics symposium explores conceptualizations of "displacement" and extends its meaning by examining its examples in the current world. It will bring together a diverse group of international panelists who will offer conceptualizations of 'displacement' in their particular context. The panelist will discuss the nuanced challenges and opportunities in their respective contexts, along with implications around intersecting equity, social, cultural, historical, and political issues involved in the science teaching and learning practices in the different settings. The panel presentations will be followed by interactive discussions, which we hope will further our understandings of the multilayered meaning of 'displacements' and what it means to empower these diverse learners and their teachers with equity-focused science learning experiences through culturally and linguistically responsive pedagogies. Potential Panelists ?Alejandro Gallard, USA Jenny Miller, Australia Maha Shuyab, Lebanon, Palestine, Syria Tamer Amin, Lebanon, Syria Minjung Ryu, USA Fikile Nxumalo, Canada Dr. Lucy Avraamidou, Netherlands Bhaskar Upadhyay, USA

Imole J. Samson Peter A. Okebukola

Exploring the Efficacy of CTCA in Breaking Barriers to Students' Learning of Difficult Concepts in Biology

Studies have shown that science in Africa stemmed from external influence and this has led to the inability of science students in Nigeria and Africa to relate with what is being taught in the classrooms. Most concepts in science are abstract, counter intuitive and not consistent with the students existing knowledge translating into the negative attitude and lack of interest students demonstrate towards science subjects which reflects in poor performance of students in these subjects. The study was carried out to proffer solution to this problem through the use of a teaching method that allows for the meaningful learning of science in Africa. The study had a survey and a quasi-experimental phase. The survey involved 1,461 secondary biology students in Nigeria and Ghana. The topic ranked as one of the most difficult was energy flow in an ecosystem. This was selected for the quasi experimental phase. The quasi experimental phase employed quantitative and qualitative data-gathering techniques. One-way analysis of covariance was applied to test for the statistical difference between the two groups. The result showed that the experimental group performed significantly better than their control group counterparts. [F (1,75) = 38.62; p< 0.05]. The implications for the study were highlighted.

Jennifer Schellinger Katarina Gomez

"Why aren't you listening to me?!: Community and Individual roles in students' epistemic agency in science

Science learning is thought to be best supported when students engage in sensemaking about phenomena in ways that mirror the work of scientists, work that requires that students are positioned as epistemic agents who share, discuss, and refine their thinking to make sense of science phenomena. Using a case study approach, we explore the experiences of one Black middle school girl, Jessie's, epistemic efforts and the ways in which her group members' responses to her efforts either supported or constrained her epistemic agency during small group work in two argumentation lessons. We view this work through the lenses of epistemic aspects of scientific argumentation, rhetorical argumentation, and pseudo-argumentation. Our findings show that Jessie's epistemic efforts were not often taken up by her peers in ways that support her epistemic agency, findings that have implications for student learning and engagement in terms of the epistemic work we ask students to engage in, and the instructional strategies that support this work.

Kathleen Schenkel

Pedagogical/research methodological approaches for analyzing power shifts in science classrooms

This paper set brings together seven emerging scholars and their collaborators together to explore diverse methodological, theoretical, and pedagogical approaches to support justice-oriented STEM education. Five papers will be presented that use different theoretical, methodological, and pedagogical approaches to explore working towards expanded learning opportunities with learners and their teachers. Additionally, these papers are situated with grade levels and formal/informal learning settings. After the papers are presented, the question of how can diverse research methodologies, pedagogies, and conceptual frameworks unite to support justice-oriented STEM teaching and learning? will be discussed by the presenters as well as the broader audience. The intentionally diverse topics of this paper set will allow the NARST community to engage how multiple approaches are needed to support justice-oriented STEM teaching and learning.

Erik J. Schettig Tamecia R. Jones

Electrifying STEM Experiences Through Hybrid Teacher Professional Development

Student success in Science, Technology, Engineering, and Mathematics (STEM) depends on teacher STEM success involving content knowledge, self-efficacy, and the application of 21st-century skills including spatial visualization and problem-solving methods. These elements of STEM learning and teaching can be enhanced through professional development experiences incorporating realistic and relatable applications of STEM concepts such as the application of electricity and coding through microcontrollers. As the consumption of electricity continues to increase, a tool becoming more and more involved in lives around the world is the microcontroller that enables the function of smart devices used to demonstrate STEM content application. Using a proposed hybrid model of professional development that incorporates multiple representations of microcontrollers, in-service and pre-service teachers can gain experience to increase their STEM content knowledge, STEM self-efficacy, spatial thinking, and problem-solving ability. This experience of using both digital representations of microcontrollers and physical components can then be incorporated into a variety of teachers' STEM curricula to provide early exposure to STEM concepts and applications leading to the development of STEM identity and success of students.

Dustin Schiering Stefan Sorge

Examining Pre-Service Physics Teachers' Pedagogical Content Knowledge – A Sequence of Proficiency Levels

Teacher education is supposed to support pre-service teachers in developing their pedagogical content knowledge (PCK). According to the Refined Consensus Model of PCK, this PCK development is mostly based on teachers' content knowledge (CK), their classroom experiences as well as their beliefs about teaching and learning science. To date, however, a complete picture of PCK development incorporating all these factors is lacking. Therefore, there is a great demand in examining how pre-service teachers' PCK changes across stages of development and analyzing the impact of different factors on these changes. To address this issue, data from N = 427 pre-service physics teachers was analyzed. Utilizing the scale anchoring procedure, four different proficiency levels in their PCK can be identified. Additionally, our analysis revealed that participants' CK is of utmost importance for an increase in PCK proficiency. However, transitions into higher levels of PCK additionally require classroom experiences and adequate beliefs about teaching and learning. Thus, our proficiency levels can be used to evaluate pre-service physics teachers' knowledge structure and bring insights into how proficiency in PCK can be promoted during teacher education.

Christine P. Schlendorf Angela M. Kelly

Equity Considerations in Earth Science Out-of-Field Teaching and Student Performance

Qualified science teachers are essential in improving precollege STEM education, however, out-of-field science teaching is problematic, particularly in lower socioeconomic schools with high teacher turnover. This census study used a non-experimental, observational approach to explore the extent of Earth science out-of-field teaching in a case study of New York State, as well as the relationship between out-of-field teaching and student performance. Teacher and school-level characteristics were also compared for in-field and out-of-field Earth science teachers. The sample included 2457 Earth science teachers during the 2016-17 school year. Findings indicated that nearly a quarter of Earth science teachers were teachers were not certified in the subject. A parametric comparison of means indicated that there was a significant difference in student performance between certified and out-of-field Earth science teachers were less experienced and taught more students of lower socioeconomic status, more English language learners, and more ethnic minorities traditionally underrepresented in STEM fields. These findings have implications for education policy makers

to improve the quality, quantity, and retention of precollege Earth science teachers, especially in urban high schools.

Paul Schlummer Stefan Heusler

Narrowing the Gap Between Experiments, Texts and Pictures – Investigation of an Extended Contiguity Principle

New technological developments such as augmented reality (AR) enable new opportunities for integrating abstract digital representations and real-world phenomena observed in hands-on experiments. While established theories of multimedia learning have extensively investigated learning from representations such as text and pictures, experiments as essential media of science education have typically not been considered within their scope. This study focuses on the well-known spatial contiguity principle for multimedia learning and investigates whether the rationale behind it can coherently be applied to experimental contexts where haptic feedback and embodied action play an important role for encoding information along with other representations. Two groups performed optical experiments assisted by an AR-environment, where the arrangement of visual representations were carried out. First results show significant differences in learning gains, indicating that increasing the spatial contiguity between experiment and additional representations leads to better learning outcomes. Therefore, spatial contiguity aspects also need to be considered when designing learning environments involving experiments – especially when the experimental setups become more complex.

Laura B. Schneider

Teaching science while socially distanced: College science laboratory instructors' experiences with synchronous hybrid courses

The purpose of this study was to investigate college science instructors' experiences teaching laboratory courses using synchronous hybrid instruction during the fall of 2020. Qualitative case study included sixteen semi-structured interviews from eight participants that were all professors or instructors in the biology, chemistry and biochemistry, or physics department at Bay College (a pseudonym), a small liberal arts college in the Eastern United States. The study explored the changes which take place when teaching a science laboratory using synchronous hybrid learning environment and found that different virtual materials such as high technology laboratory notebooks and digital learning materials such as online databases became important parts of synchronous hybrid courses. Instructors felt it was important to select materials that did not burden students with additional costs. Another change was what skills were emphasized in the laboratory courses. There were also student equity issues when it came to access to electronic technology and internet. The study also examined what college lab instructors' experiences were with teaching a laboratory in synchronous hybrid learning environments and found that there were numerous challenges and new responsibilities reported by laboratory instructors. This study has implications for colleges considering changing how courses are offered.

Odelia Schrire Dina Tsybulsky

The Experiences of Biology Teacher Coordinators Participating in a VPLC During the COVID-19 Crisis

This study provides an in-depth examination of the experiences of 25 biology teacher coordinators participating in a Virtual Professional Learning Community during the COVID-19 epidemic. The study presents the focal points of the coordinators' experiences that arose in their personal stories and in the context of their participation in the community. This study was a qualitative narrative study and data were collected from in-depth interviews and observations of community meetings. Thematic analysis was done to examine participants' main foci of experience in the educational-technological context and in the context of their participation in the community during the COVID-19 crisis. The findings of the study show that in general, the community supported the coordinators in tackling the challenges of the period. The focal points of the experiences reflected their feelings and their desire to receive professional and emotional help during this period and showed that the community has a central role in providing professional help and assistance. The community has in fact provided additional space for the professional development of biology teacher coordinators amid the frequent changes that have characterized teaching during COVID emergencies.

Martin Schwichow Anastasios Zoupidis

TEACHING AND LEARNING FLOATING AND SINKING: A META-ANALYSIS

Floatingand sinking (is a main topic in science education, both at primary and secondary levels. At the same time, the interpretation of FS phenomena is challenging because of the difficulty of the scientific concepts and explanatory models involved (e. density, buoyancy), along with everyday experiences students have which interfere with the scientific explanations. Consequently, in the last few decades, many studies investigated how to teach FS effectively to students of different ages utilizing multiple teaching approaches. This meta analysis summarizes the findings from 70 intervention studies on teaching FS conducted between 1977 and 2021. Over all studies, we estimate d a mean effect size of d 1.02 (CI 0.87 1.17) Moreover, in a moderator analys i s we investigate the effect of design features, student characteristics, intervention characteristics, and assessment features on the mean study effect size. To analyze the effect of these moderator variables, we use a two level hierarchical meta regression model with robust estimations of standard errors for dealing with multiple effect sizes from single studies. We discuss the implications of our findings regarding the moderator variables for effective teaching of FS and further research on FS.

Andria C. Schwortz Andrea C. Burrows

Listening to Find Integrated STEM Discourse: Power and Positioning During a Teacher Professional Development STEM Activity In this case study, the authors seek to understand and characterize the discussions of STEM teachers among themselves when working with a 200-entry astronomy dataset using a web-based spreadsheet tool. Five in-service STEM primary and secondary teachers were audio and video recorded while working on the activity for two hours. The participants positioned group members with higher social status (based on gender, degrees, experience, etc.) as peer mentors. The peer mentors controlled the computer and guided the others to develop pedagogical content knowledge. The computer was also used as a technological bridge between science and math concepts. Participants not only integrated STEM concepts in their discussion, but also made connections to the science-adjacent topics of geography and technical writing.

Sylvia Scoggin Rebecca Curtright

A District Perspective on Developing a Three-Dimensional Science Assessment

This related paper set presents the results of our work developing and implementing a threedimensional district biology assessment within the context of a research-practice partnership. We include our practice partners as lead co-authors to demonstrate our commitment to valuing practice perspectives in science education. Paper 1 describes the district science curriculum coordinator's decision-making about the development of the assessment, including successes and challenges of the process. Paper 2 describes how the district implemented the assessment and used the data from administration of the assessment to all high school biology students in the district. Paper 3 investigates teachers' professional learning experiences as an item writer on the assessment development team. Finally, Paper 4 investigates students' reasoning on the assessment using a think-aloud protocol. Altogether, these four papers highlight different aspects of the development and implementation process of a district science assessment from both practice and research perspectives and contributes to our understanding of the challenges of enacting educational reforms in complex educational systems.

Wisam Sedawi Orit Ben Zvi Assaraf

Exploring Sense of Place across Generations: A Case study of a Negev Bedouin Community

The Bedouins of the Negev Desert are an indigenous people, a sub-group within the Arab minority in the state of Israel. Like other indigenous populations, Bedouin society has been undergoing a relatively rapid process of settlement and modernization. The study presented here focuses on an intergenerational examination of sense of place– examining the perceptions of both adults and children from a Bedouin community living on the banks of the highly contaminated Hebron stream. Data were gathered using semi-structured, in-depth interviews. The interviews provided basic information about the children and adults' experiences in the stream and its environment, and about the attitudes that arise from these experiences. The data were subjected to qualitative analysis. The results of the study illustrate various aspects of the differences in sense of place between the children and adults, and how these relate to the changes undergone by their environment over time. This offers a unique opportunity to explore the specific ways in which sense of place influences and is influenced by shifts in cultural, physical and political-economic circumstance. Understanding these can be a preliminary step to the development of

place-based environmental education programs that actively engage the community in the preservation of their local environment.

Quentin C. Sedlacek

Who gets to sound "like a scientist"? Scientific language as a process of authentication

This related paper set draws on raciolinguistic perspectives to raise new questions about racialization, language, and power in science education research, pedagogy, and teacher education. Each paper draws on recent scholarship from Jonathan Rosa and Nelson Flores to shift the gaze from the linguistic practices of racialized speakers (e.g., are minoritized students acquiring 'scientific language'?) onto the professionalized practices of the listening subject (e.g., how are teachers expected to arbitrate who is speaking or writing 'like a scientist'?). The first three papers turn scrutiny onto prevailing modes of perception in U.S. science education. Through analysis of science teacher surveys, language expectations in science course materials, and pre-service teacher interviews and small group discussions, these papers illustrate exclusionary processes of linguistic authentication, racializing appraisals of disciplinary legibility, and the typologizing of who is identified/identifiable as 'talking science.' The fourth paper situates these patterns in historical perspective by examining how similar raciolinguistic distinctions took shape in the segregated science instruction offered to Mexican American students a century prior. Together, the papers interrogate foundational assumptions shaping the White-perceived listening subject of U.S. science education to open a more robust dialogue concerning linguistic and racial justice in the field.

Emily Rose Seeber Christa Haverly

Pathways to Critical Practice in Elementary Science Education

Approaches to learning which centre equity and challenge racist and colonialist hierarchies of power in schools are increasingly prominent in academic discourse. Freire's (2017 [1970]) critical socioculturalism provides a theoretical lens that can support teachers and researchers in thinking about science education for social change: science education which actively disrupts existing inequities and empowers young people to engage morally, politically, and scientifically with the world around them. However, the challenge for teacher educators is how to support teachers and teacher leaders in appropriating and leveraging these theoretical ideas in their day-to-day science instruction and instructional leadership. This study draws on interviews with 28 district science coordinators describing their visions for elementary science instruction to describe five aspects of the theory (or 'pathways' into the theory) which resonate with their experiences, immediate needs and concerns, and take their current beliefs about learning into account. These pathways to critical practice can be leveraged by teacher educators looking to design professional learning opportunities for elementary science teachers and teacher leaders.

Helen Semilarski Regina Soobard

EXPLORING THE COMPLEXITY OF STUDENT-CREATED MIND MAPS, BASED ON SCIENCE-RELATED CORE IDEAS

The success of science education is in promoting conceptualization, both disciplinary and interdisciplinary, in meeting desired learning goals. This research seeks to identify the quality of, upper secondary school students' dimensions of knowledge and conceptualization, related to a set of sciencerelated disciplinary and interdisciplinary core ideas. Using validated guidelines, data collected from grade 10 and 8 (N=254) students, and an abductive thematic analysis approach are used to subsequently analyze student-created mind maps. Results show that most students are able to create mind maps, although these tend to be very general and indicate few interconnections between the different dimensions of knowledge presented. The results further suggest that, in general, it is difficult for students to conceptualize the interrelationships between science-related disciplinary and interdisciplinary core ideas and even show that some students hold misconceptions. The use of mind maps is seen as a meaningful approach to identifying learners' ability to relate dimensions of knowledge applied to disciplinary and interdisciplinary core ideas in science education. The research identifies a need to investigate learning approaches in secondary school studies so as to promote more emphatically interconnections between disciplinary and interdisciplinary core ideas. Keywords: conceptualization, disciplinary core ideas, interdisciplinary core ideas, dimensions of knowledge, mind maps

Helen Semilarski Regina Soobard

USING STUDENT-CREATED CORE IDEA MAPS TO PROMOTE MEANINGFUL LEARNING IN SCIENCE

The goal of this research was to determent students meaningful learning in science classes by involving students in creating core idea maps, based on the structure of mind maps. The approach was (a) creating 10 curriculum-related, core idea maps (by science educators), (b) teachers guided students in making interdisciplinary connections and creating core idea maps in an intervention lasting a year and a half from grade 10 to 11 (c) giving feedback on student-created core idea maps, (d) administering questionnaires, seeking students' perceptions about their self-efficacy towards core ideas as an indicator of meaningful learning, both before and after the intervention, (e) interviewing science teachers (5) and selected students (25), after the intervention about their perceptions towards the use and outcomes of creating core idea maps. Besides the experimental group, a control group (no intervention) was involved. The results indicated that there is a need for students to more clearly conceptualize a framework of core ideas, shown to be important for enabling students to prepare for their future. The results from this research is that improving students' perceived self-efficacy can facilitate meaningful learning. Keywords: Core ideas, core idea maps, interdisciplinarity, knowledge construction, meaningful learning, self-efficacy

Elsun Seung Vance J. Kite

Understanding Elementary Preservice Teachers' Beliefs about the Importance and Value of the NGSS Science Practices

This study explored elementary preservice teachers' beliefs about the importance and value of the NGSS science practices. An open-ended survey was used to collect quantitative and qualitative data from 83 preservice teachers. Quantitative data were analyzed for average ranking scores and frequencies to identify science practices that preservice teachers perceive to be the most important for student learning. Qualitative data were analyzed using qualitative content analysis to understand why and how the teachers valued each of the practices. The expectancy-value theory (Wigfield & Eccles, 2000) served as both theoretical and analytic framework for the study. Data analysis indicated that preservice teachers ranked Asking questions, Planning and carrying out investigations, and Analyzing and interpreting data as the top three most important science practices. In contrast, Obtaining, evaluating, and communicating information and Engaging in argument from evidence were ranked as least important. Preservice teachers attached attainment value most frequently to the scientific practices that they chose to be most important for student science learning. The results of this study imply that preservice teachers have limited understanding of the principles of NGSS, which intertwine science content learning and science practices under the umbrella of crosscutting concepts and epistemic nature of science.

Samuel Severance Guadalupe Martinez

Supporting Teachers' Capacity to Design for Coherent Assessment of Multidimensional Science Learning

This design-based research study explores how to support middle school science teachers in engaging in coherent assessment of multiple dimensions of science learning. Assessing how students engage in knowledge-in-use of the different dimensions of science learning, and doing so in a coherent manner monitor how students' learning builds over time, should be an essential aspect of shifting instruction to meet the vision of the Framework for K-12 Science and Next Generation Science Standards. Researchers for this project have developed numerous three-dimensional science learning tasks aligned to learning performances, smaller slices of targeted performance expectations. Five science teachers from California were recruited and asked to incorporate tasks into an existing unit so as to be able to better monitor students use of the different dimensions of science learning and the coherence of their learning over time. In addition to PD and meeting in small design groups, teachers were given a design "mapping" tool to analyze an existing curriculum and find corresponding assessment tasks. Findings indicate teachers' time proved a limiting factor in using tasks, published curriculum proved an enabling factor in using tasks, the "mapping" tool promoted teacher engagement with coherence, and while engagement in small design groups was productive, learning from the initial PD was not sustained.

Asli Sezen-Barrie Malcolm B. Butler

Future Directions for Research on Equitable and Socially Just Assessments in Science and Engineering Education

Abstract / General Overview of the Panel The goal of this year's 'Research Committee Administrative Session' is to discuss recent theoretical and empirical research on equitable and justice-oriented

assessment design aligned with the recent reform efforts outlined in the Framework (National Research Council, 2012), Next Generation Science Standards (NGSS, 2013, and Developing Assessments for the NGSS (NRC, 2014). To put forward an agenda for the engagement of historically marginalized learners in science classrooms, these documents highlighted promising strategies such as phenomena-based learning to increase relevance to all learners and engineering design process for diversifying activities in science classrooms. Based on their recent research, the panelists in this session will present ideas and pose questions on the impact of current reform on the design of assessments. The panel will start with a discussion of inequitable assessment practices due to the deficit model of NGSS alignment as a technical problem. Then, panelists will provide examples of tensions science education leaders and teachers face in designing, aligning and implementing justice-oriented assessments of science learning. While considering attention to equity and diversity as an affordance, the panel will question whether equity is at the center in the reform-based assessment culture. Afterwards, we will look at examples of a) how equitable assessment practices can be integrated into the engineering design process; b) how linguistically responsive pedagogies can provide a lens for fair assessment opportunities for multilingual learners, and c) how we can move beyond "accommodation" and "modification" of assessment tasks for underrepresented groups by moving beyond the traditional ways of assessments in science classrooms. The panel will conclude with a question-and-answer session on the role NARST members can play in creating a research agenda for equitable and justice-oriented assessments of student learning in science and engineering education. Panelists Gavin Fulmer, National Science Foundation, University of Iowa, How Could Lack of Alignment Create Inequitable Assessment Systems? Erin Furtak, University of Colorado at Boulder, I am the White assessor: Grappling with dominant paradigms in Frameworkaligned formative assessment William Penuel, University of Colorado at Boulder, Developing Justice-Focused Assessment Tasks: Tensions and Possibilities Sheron Mark, University of Louisville, Addressing equity from the margins: Outcomes of teacher professional development practice Christine Cunningham, Pennsylvania State University, Engineering Curriculum Design for Equitable Assessments Caitlin Fine, Boston College, Translanguaging as a Linguistically Sustaining Science Formative Assessment Design Framework Enrique Suarez, University of Massachusetts at Amherst, How do we know? The Implications of Translanguaging for Equitably Assessing Multilingual Students' Science Learning Hosun Kang, Seoul National University, South Korea, Moving Beyond the 'Accommodation': Expanding What it Means to Be Good and Learn Sciences Using Non-traditional Assessments Panelist Presentations 1. How Could Lack of Alignment Create Inequitable Assessment Systems? Gavin Fulmer, National Science Foundation, University of Iowa I will explore alignment and related factors that could lead to inequitable assessment outcomes, ranging from narrow to broad contexts. We may think of alignment as a purely technical problem for curriculum and assessment developers, drawing on its basis as some degree of match with intended standards. But this belies the importance of understanding alignment with rigorous standards that emphasize the epistemic practices of science. Assessments that are misaligned or lack any alignment evidence could lead educators to set different expectations for students, producing inequity in their opportunity to learn, and also provide widely different interpretations of students' capabilities, affecting their educational outcomes and future attainment. 2. Developing Justice-Focused Assessment Tasks: Tensions and Possibilities William R. Penuel, University of Colorado Boulder The Next Generation Science Standards (NGSS Lead States, 2013) include many performance expectations that require students to develop understanding of how human systems shape phenomena. Engagement with such systems invites students to pose questions about history, power, and justice: How did this phenomenon come to be? What institutions make decisions about this problem? Why are the consequences of this problem unfairly distributed? Why here and not there? Yet science and engineering are often presented as apolitical (Morales-Doyle et al., 2020), and teachers who do seek to consider justice in teaching and assessment face multiple challenges. In this talk, I draw on experiences

of co-design with science education leaders to characterize both tensions and possibilities that teams face in constructing tasks that frame problems to be solved in ways that foreground matters of justice and describe how one team designed professional learning to address these across states with divergent political environments. 3. I am the White assessor: Grappling with dominant paradigms in Frameworkaligned formative assessment Erin Marie Furtak, University of Colorado at Boulder Current science education reforms emphasize science learning opportunities should center on the ideas and experiences of historically marginalized students (Bang et al., 2013; NRC, 2012). Classroom assessment must not only align with, but deepen these initiatives (NRC, 2014); however, assessment design and enactment can limit students to ideas and ways of knowing consistent with dominant paradigms (e.g. Dini et al., 2020; Fine & Furtak, 2020). At a time when most US science teachers identify as White (Banilower et al., 2018), this means that many science teachers need to interrogate their own knowledge and understandings so they can authentically listen to and engage with their students. In this presentation, I reflect on my own identity as a White teacher and educational researcher, grapple with the consequences of teaching and assessing from this perspective (Paris, 2012; 2019), and pose critical questions for the field. 4. Addressing equity from the margins: Outcomes of teacher professional development practice Sheron Mark, University of Louisville What are the affordances and limitations of reform documents in creating an assessment culture with equity at the center? Earlier research efforts (Mark et al., 2020) sought to explore this question by investigating the outcomes of a Next Generation Science Standards (NGSS) professional development for classroom teachers. While NGSS' more explicit stance on equity and diversity in science education is an acknowledged affordance, issues persist with NGSS' structure and the sociopolitical context within which NGSS is being implemented that, if unaddressed/unresolved, may limit NGSS' promise. These limitations are, furthermore, understood to be present despite educators' efforts towards authentically and meaningfully implementing NGSS. In characterizing the outcomes of the NGSS PD efforts, a set of robustly considered and researched equity-driven practices that were, furthermore, generalizable, was constructed through a review of literature. These practices served as a framework to discern trends regarding how an NGSS lens facilitated/aligned with equity-driven science education. 5. Engineering Curriculum Design for Equitable Assessments Christine M. Cunningham, The Pennsylvania State University Equitable and socially just assessments need to be integrated into the design features of the curriculum and pedagogy experienced by students. I present a set of design principles supporting the development of equity-oriented engineering and science lessons. For each, I provide illustrative examples from Youth Engineering Solutions (YES) curricula. YES situates engineering problems in the local community, requires students to balance multiple perspectives, and focuses on the potentially disproportionate impacts of technologies on communities and society. Also central to understanding engineering is engagement in disciplinary practices. Thus, YES assessments focus teachers on recognizing learning related to socially engaged engineering and epistemic practices of engineering. As students engage in iterative cycles of design, formative evaluation prompts guide teachers to gather evidence of student learning from written and oral experience and reflection. Summative assessments include rubrics and engineering notebooks where conceptual and epistemic tools may be evidenced in student work. 6. Translanguaging as a Linguistically Sustaining Science Formative Assessment Design Framework Caitlin Fine, Boston College Science reform efforts call for a more inclusive approach to science learning that builds on multilingual learners' heterogeneous linguistic practices (NRC, 2012). This is particularly important in assessment, as educators often make instructional and placement decisions based on what multilingual learners demonstrate they know and can do (Mahoney, 2017). Translanguaging pedagogies (Garci?a & Wei, 2014; García, et al., 2017) offer a linguistically sustaining framework to support these science reforms. Translanguaging is the communicative norm of multilingual communities where speakers choose to deploy various linguistic practices depending on their context (Otheguy, et al., 2015). In this presentation, I explore challenges

and opportunities faced by a teacher-researcher collaborative as we designed and interpreted science formative assessment tasks that made space for multilingual 6th graders to translanguage in an Englishmedium school. Results suggest the importance of engaging in this work in an iterative and contextualized way, especially in the face of district-level accountability systems. 7. How do we know? The Implications of Translanguaging for Equitably Assessing Multilingual Students' Science Learning Enrique Suarez, University of Massachusetts at Amherst If we observe the Sun only through the UV end of the spectrum, we would never truly understand its complexity and beauty. Similarly, while eliciting, analyzing, and responding to students' reasoning advances equity in science education (Thompson et al., 2016), our assessment practices must also be rooted in culturally and linguistically responsive and sustaining pedagogies (García & Kleifgen, 2019; Paris & Alim, 2014). Toward these ends, I use translanguaging as a theoretical and pedagogical framework for recognizing and leveraging the complex communicative practices of multilingual learners, without policing semiotic boundaries (Otheguy, García, Reid, 2015). I will share cases that illustrate the translanguaging practices of elementary-aged multilingual learners, showcasing the range of semiotic resources that they deploy when problematizing phenomena and constructing mechanistic explanations. My goal is to elevate the multilingual, multimodal, and multisensory nature of communication (Li, 2018; Suárez, 2020) and caution against the pervasive English- and logo-centric designs of science assessments. 8. Moving Beyond the 'Accommodation': Expanding What it Means to Be Good and Learn Sciences Using Non-traditional Assessments Hosun Kang, Seoul National University, South Korea (hosunkang@snu.ac.kr) 'Accommodation' or 'modification' of assessment items or procedures for a particular group is the current dominant paradigm of promoting equity through classroom assessments. In this talk, I discuss the limitations of this approach in addressing inequity and injustice experienced by minoritized students at schools. Building a conceptual argument that addressing inequity and injustice in science classrooms involves expanding minoritized students' meaningful opportunities to learn (OTL), I propose building a new classroom assessment system that uses deliberately designed curriculum-embedded nontraditional assessments with the goal of radically expanding what it means to be good, do and learn sciences at schools. Using one co-designed high school physics unit about momentum, I illustrate what the classroom assessment system might look like and how minoritized students respond to it. Notes: Suggested Date and Times: 1st or 3rd day of the NARST Conference 1:45 -3:30pm EST Tentative Schedule (105 mins) Introduction to Panel: 10 mins Panelist Presentations: 80 Mins Question and Answer: 15 mins

Neta Shaby Dana Vedder-Weiss

Measuring Electro Dermal Activity (EDA) to detect and identify emotional engagement during family science activities

Engagement with science practice and content in everyday family life is abundant, especially during the current COVID19 pandemic that highlights most acutely the significant role of family learning. Furthermore, research on emotions in education is scant. In this study, we demonstrate a new approach for exploring individual emotional engagement during family science activities using Electro Dermal Activity (EDA) measures. We used wearable mobile equipment to collect psychophysiological data (primarily EDA) of one participant, Irit, a mother of four children and a science teacher, during five family science activities. To analyse the EDA data, we used Peak Analysis Module for LabChart software. Overall, we detected 184 peaks in all five activities. Our findings suggests that for this particular
participant, watching a science video elicit various emotions whilst doing homework with her daughter prompt one dominant emotion (anger). This work can contribute to research on emotional engagement related to learning, interest, and identity development. We argue that this method is promising yet still a work in progress. As family science learning becomes more essential in our life, this method may assist researchers to better understand the role of emotional engagement in it and the implications to other areas.

Neta Shaby Dana Vedder-Weiss

Innovative approaches to theorizing and studying family STEM learning

The nature of STEM learning is changing worldwide, as people have access to STEM education resources not only in school but also in a variety of settings across their lifetime. Family engagement with STEM facilitates disciplinary talk, supports scientific thinking, and scaffolds understanding of science, thus playing a critical role in children's development of STEM knowledge, skills, interest, and identity. This symposium is based on the notion that family-based STEM learning involves unique characteristics, such as intergeneration relationships, serendipity, shared history, and continuity across settings and time, that need to be better conceptualized and require adjusted methodologies. It brings together an international collection of scholars for a presentation of five studies on family STEM learning, to discuss different theoretical frameworks (family systems, equity, interest development, and resources appropriation) and various qualitative methodologies)longitudinal case studies, video-based micro-ethnography, self-ethnography, home video recording, and video stimulated recall interviews). The set of presentations also focus on a variety of audiences (including traditionally marginalized communities and children at different ages) and covers a range of learning settings, such as mobile-based learning within an outdoor space, family-based engineering education, home engineering kit activities, and serendipitous learning in different settings of family everyday life.

Sheikh Ahmad Shah David W. Jackson

Design and Outcomes for Computational Interest, Competency Belief, and Anxiety in "Science for Future Presidents"

Computational literacy is a vital competency for all learners, including the under-researched population of grades 13-20 non-science majors taking science courses. In this study, 21 undergraduate students in a "Science for Future Presidents" course built an automated mini-greenhouse, including block-based coding with BBC Micro:bit, over a four-week project. We report on the second iteration of design-based research. Using a mixed-methods convergent design, we conducted a pre-survey and a post-survey to check the interest, competence belief, and anxiety about coding and computation. We analyzed those quantitative data alongside qualitative data generated from student work samples from the middle and end of the "smart greenhouse" project. Our analyses found a statistically significant increase of interest and competence belief (Cohen's d of .64 and .43, respectively). Notably, the change in anxiety about coding was not statistically significant. Qualitative analyses suggested that the project resonated with students' interests in topics adjacent to or outside of science, technology, engineering, and mathematics

(STEM). Key design considerations included asynchronous videos, synchronous office hours, and both teacher- and student-directed explorations of computational literacy. We conclude with implications for educational design, as well as undergraduates' during-course and post-course conceptual, affective, and emotional development.

Elica B. Sharifnia Daryl Greenfield

Examining the Relationship between Preschool Teachers' Attitudes and Beliefs towards Science and Classroom Practice

Despite growing national attention to the importance of science for young children, there is still little research focused on promoting science learning in early childhood education. Teachers' attitudes and beliefs toward science play a critical role in supporting high-quality science education. However, limited research has focused on better understanding how preschool teachers' attitudes and beliefs towards science may impact their classroom practice, including the frequency and quality of science instruction. To address this gap, the current study examines the relationship between preschool teachers' attitudes and beliefs towards science (specifically related to the following: (1) comfort in integrating science (Teacher Comfort), (2) whether they view science as beneficial for children's learning (Child Benefit), and (3) perceptions of the challenges of supporting children's science learning (Challenges)) and their frequency and quality of science instruction in their classroom. Thirty Head Start Teachers participated in this study. Results indicated a positive significant relationship between teacher's report of the Teacher Comfort factor and their frequency of science instruction. However, there no significant relationships between teacher's report of the Teacher Comfort factor and their frequency of science instruction. However, there no significant relationships between teachers attitudes are discussed in terms of implications for professional development and interventions around early childhood science education.

Meenakshi Sharma

Use of Science and Engineering Practices to Create Equitable STEM Learning: Implication For Teachers' Anti-deficit Noticing

This related paper set responds to calls for re-imagining disciplinary learning in science (Warren et al., 2020) and "broadening participation" in STEM (NSF Includes, 2019). Specifically, the papers in this session will explore practices such as anti-deficit noticing as ways to support equitable science teaching and learning. Deficit ideologies can lead researchers and educators to blame students for perceived deficiencies in school rather than attending to the social structures that limit students' opportunities for learning (Peck, 2020; Philip, 2011). Anti-deficit noticing (Louie et al., 2021) is a teaching practice that explicitly challenges these deficit ideologies by (1) identifying deficit frames that limit students' opportunities for learning and (2) shifting toward anti-deficit frames that empower minoritized students. While anti-deficit noticing is becoming increasingly prominent in math education (Louie et al., 2021), less is known about how this practice can be supported in science education. In response, this session will offer an illustrative example of anti-deficit noticing in a secondary science classroom, and it

will explore anti-deficit approaches to preservice teacher education and in-service teacher professional development.

Anat Shauly Gabriella Shwartz

The role of professional learning communities (PLCs) in supporting chemistry teachers during the COVID- 19 crisis

During the COVID-19 Pandemic, schools shifted to Emergency Remote Learning (ERT). This reality led teachers to seek support. Professional Learning Communities (PLCs) were one source of support. In a PLC, teachers meet regularly for discussions, joint learning, and collaboration. Our research aimed to describe teachers' work and study PLCs' support, during ERT. This study compared PLC members with non-members. Differences in spoken language among participants were accounted for. Data was collected by semi-structured interviews and a questionnaire. Chemistry teachers' knowledge was analyzed using the Refined Consensus Model for PCK. Learning new tools, assessment techniques, and teaching practices contributed to teachers' PCK; teachers reported this was essential for teaching online. Results showed PLC members found group support beneficial during transition to ERT, while non-member teachers were self-reliant. Furthermore, communities provided support to all regardless of speaking and teaching language. PLCs were supportive and contributed to PCK, so we recommend broader access to them. The enhancement of PCK and support given in PLCs to diverse teachers shows their potential in promoting inclusion of variety chemistry teachers in communities, extending cooperation outside school boundaries to regional, national levels and beyond.

Kelly Marie Shepard

Expression of Next Generation Science Standards in Picture Books

This study examines the expression of the Next Generation Science Standards (NGSS) in science-themed picture books written for K-5th grades. This study is a content analysis of the text found in the picture books and is rooted in research that finds integrated science and reading are valuable for students' understandings of scientific concepts. The sample is comprised of picture books selected from the recommendations of professional organizations devoted to science and science education. It includes picture books about life, Earth/space science, and physical science. A deductive content analysis methodology is used to identify the analyzed text and applies a coding system that identifies the presence of the NGSS in picture books. Descriptive statistics and qualitative data analyses are used to reveal the themes related to the picture books and the NGSS. This study finds that a large majority of the analyzed picture books express NGSS for K-5th grades. Most picture books express the NGSS at the grade levels for which they are recommended. The study is limited and does not examine the use of scientific vocabulary or images. This study contributes to the research on the intersection between science and reading for elementary grade levels.

Soo-Yean Shim Kevin Hall

Proposing a Framework to Analyze Educative Features in NGSS-aligned Science Curricular Materials

This study suggests a framework for analyzing features of science curricular materials that are educative, that is, help teachers build capacity to notice students' ideas and plan and enact NGSS-aligned instruction. We analyzed ten lessons across four research-based, NGSS-aligned units, developed by two developer organizations. The units were phenomenon-based and emphasized instruction that builds on students' ideas and practices. Through an iterative process of developing, applying, and revising codes, we identified specific features of curricular materials that can promote teacher learning: attending to student thinking, attending to disciplinary ideas or practices, attending to connections across lessons, providing explanations of instructional tools/practices, and providing instructional choices. We found various ways these features were addressed in curricular materials, which suggests that the features could be "educative" in different ways. The range of ways included: just describing ideas (e.g., student ideas or disciplinary ideas), suggesting interpretation or explanation of ideas, proposing instructional ways to address ideas or assess student understanding of ideas. Our future work will focus on understanding how teachers interact with these features in planning and teaching.

Myunghwan Shin Jane J. Lee

Placing Empathy at the Center of Engineering: Design Thinking Embraced by Preservice Teachers for Engineering Design

Despite the increased significance of engineering design in K-12 science education and teacher education, the ways in which engineering design is represented in schools are criticized by scholars due to their lack of attention to the social, political, or human aspects of engineering. This study aims to explore how preservice teachers embrace design thinking for their human-centered engineering design projects in a science, technology, engineering, and mathematics (STEM) education course offered by a US teacher education program. Using ethnographic research methods, we examine how preservice teachers experience engineering design for developing sustainable communities guided by the mindsets and process of design thinking and what they learn from teaching engineering design. We present three key themes that emerge from our data: 1) engineering with empathy reveals new insights, 2) caring for people promotes expanded learning, and 3) creative confidence in engineering.

Mary E. Short

Identifying Evidence of Student Global Discourse in Socioscientific Issues Research

This theoretical paper draws on social theory found across global education literature to present a conceptual framework for identifying elements of global student discourse. The framework is applied to seminal research on socioscientific issues-based education to assess how global student discourse is attended to in the 10 most cited SSI papers. In the final section, the paper discusses the findings of the review along with their implications for seeking a unified and inclusive vision for global scientific literacy.

Merav Siani Anat Yarden

Are Knowledge and Acceptance of Evolution Aligned among Jewish Religious Preservice Science Teachers?

Using human examples when teaching evolution has advantages (e.g., motivating students to study and remember evolutionary concepts), yet human evolution meets even more resistance than animal and plant evolution. The aim of our research was to address the relationship between knowledge, acceptance and religious background by evaluating the impact of a human evolution intervention unit on the evolution knowledge and acceptance of 23 Jewish religious pre-service science teachers. In addition, we looked into the acceptance of evolution before and after experiencing the unit and tested the alignment between evolution reasoning and acceptance. We collected data using three research tools: Analysis of open ended answers imbedded in the online activity, structured interviews held a few months after the online activity, and the Inventory of Student Evolution Acceptance (I-SEA) questionnaire. A main conclusion of this research is that there was an increase in the total acceptance of evolution after the online interactive activity, especially human evolution. In addition, there is no clear correlation between evolution acceptance and evolution knowledge. We therefore suggest addressing the issues of knowledge and acceptance separately, in a culturally competent way, especially when dealing with religious participants.

Marcelle Siegel Yejun Bae

Building Inclusive Excellence in Undergraduate Science Education through Faculty Learning Communities: A Study of Five Cohorts

Teacher learning and faculty development are critical targets for transforming higher education for equity, yet are often not prioritized in undergraduate education. Faculty Learning Communities (FLCs) have been effective routes for developing faculty and making changes to the undergraduate experience. Based on this, we organized FLCs to address the major needs on campus for inclusive excellence and aimed to create an FLC model that promotes STEM faculty's inclusive and anti-racist teaching practices. In this study, framed by a communities of practice perspective, we analyzed data from five FLCs over three years. Data sources included FLC session discussions, online discussions, interviews with faculty, and survey responses. Using a grounded theory approach to examine faculty understanding of inclusive teaching, (2) faculty growth as change agents, and (3) transformative actions taken in classrooms and institutional spaces. We hope that our work highlights faculty's heightened capacity as change agents and this enhanced legitimacy will support NARST members in enacting change in their higher education communities. NARST members concerned with undergraduate education, equity, institutional change, and professional development might find interest in this paper.

Tiffanyrose Sikorski Erica Wortham

Engineering students' self-efficacy and civic responsibility in a social innovation curriculum

A well-established curriculum in engineering schools places emphasis on preparing students to be innovators. While engineering programs typically highlight the economic opportunities post-graduation, students are increasingly interested in "ways to leverage their engineering education to pursue impact-focused careers where they can tangibly see the human impact of their work." This project recognizes that social innovation could be important to improve students' engagement in their engineering education. Social innovation also requires students to learn new skills that are not typically taught in the engineering curriculum, such as human centered design and problem solving with empathy. By helping students develop these skills, they will be in a better position to use their knowledge in the future to support more equitable societies. Sophomore students across different engineering disciplines took a social innovation course that presented social innovation as a core commitment of the engineering profession. As students engaged with this curriculum, they reflected on their self-efficacy in engineering and strengthened their sense of civic awareness infused with empathy. These findings suggest that examining complex societal challenges will catalyze engagement, retention and participation in engineering while providing a deeper understanding of the field that are often posterior to the engineering education curriculum.

Maria C. Simani

How can culturally responsive teaching be framed as creative endeavor through adaptation design principles?

Adaptation design principles that teachers use for enhancing student learning How can teacher professional learning be designed to promote teacher agency and responsive teaching? The goals for professional learning are multifaceted due to complex demands placed on teachers. While enacting curriculum, a teacher must be equipped to engage students productively. They must improvise teaching to support science practices and build on student experiences and current understanding, create equitable and culturally relevant contexts, and support social and emotional learning. This team of researchers from three universities presents a set of disparate but consequential design principles centered on supporting teachers to adapt curriculum according to context, focused on different teachers and grade levels, but all enacting Project-based Learning. An adaptation design principle is an actionable, evidence-based claim that teachers employ to navigate adaptations so teaching sustains the deeply rooted foundations of productive and responsive science teaching. Paper 1 explains the process for using adaptation design principles to frame Professional Learning. Paper 2 describes design principles for creating equity-centered environments, paper 3 is centered on the design principles that support engagement in developing, using and presenting models, paper 4 shows how adaptation design principles can be used in Professional Learning to leverage adaptations based on culturally responsive teaching.

Jonathan Simmons Todd Campbell

Intergenerational Family Learning in Conservation Science

Families create contexts for learning to enhance and support the interests of their children, while simultaneously teaching language, morals, and culture. This research examines intergenerational family teams engaged in a long term conservation project in their community. Participants were interviewed during and after project completion with the central research purpose of exploring how the intersecting experiences of family members explain emerging family cultural learning pathways. Intergenerational family teams shared narratives which were then analyzed using the cultural learning pathways framework (Bell et al., 2012) that we subsequently used to create family cultural learning pathways for each participating family. Family interactions are powerful influences on the identity development of children, not only in their academic development, but also in their moral, ethical, and social development. This research provides insight into family learning by providing examples of the nuanced and complex ways that families develop interests, identities, and learning across time and space.

Jonathan Singer Jacqueline Krikorian

Exploring Early Enactment Attempts for Integrating Engineering Design Practices in High School Biology

The present study builds upon our prior investigations by taking an in depth look at teachers' initial attempts at integrating elements of engineering design into high school Biology classrooms. Work presented in this poster utilizes a classroom observation instrument Innovation Configuration Maps (IC Maps) that provided a targeted analysis related specifically to the integration of Engineering Design practices (Custer et al., 2014). The IC map observation data analysis also provided the identification of two teacher cases that were further investigated via qualitative means to illustrate initial efforts with the integration of engineering in high school Biology classrooms. The data were obtained from classroom recordings at nine time points across three years. Initial Quantitative findings demonstrated that in general the Biology teachers were able to integrate engineering design principles in their classroom instruction when provided exemplar lesson plans. Teachers' ability to develop their own lessons with elements of engineering design did not demonstrate consistent growth across the three years of the study. Findings from the case study can illustrate specific instructional practices that should be focused upon as curriculum supports and/or as practices to be explicitly addressed during teacher professional development.

Harleen Singh Hatice Ozen_Tasmedir

Knowledge, Practices, and Attributes of International Science Coordinators and the Resources They Draw Upon: Supporting Teachers During the COVID-19 Pandemic

This qualitative study explores the meaningful experiences of science coordinators from different parts of the world during the school closures due to the COVID-19 pandemic. In particular, it aims at understanding the shifts in knowledge, practices, and attributes of science coordinators and the resources they have drawn upon that have helped support science teachers during this time. The participants of this study were 15 science coordinators from 10 countries, including Canada, Chile,

Mainland China, India, Kenya, Pakistan, Turkey, Taiwan, United States, and Vietnam. This study uses the concepts of organizational resources and capital as the framework to understand the experiences of school science coordinators. Data for the study were collected in the form of semi-structured interviews. Interviews were analyzed thematically using two cycles of inductive coding. Findings from the study indicate an increase in knowledge, practices, and attributes of technology (was required for the shift), collaboration, creativity, and interpersonal skills. The majority of the practices and attributes that were important during the pandemic were related to working with people (soft skills). SCs' knowledge, practices, and attributes in the form of social and material resources available to the teachers. Implications of the study are discussed.

Mamta Singh

Assessing Elementary Preservice Teachers' Knowledge, Awareness, Attitude, and Beliefs Toward Environmental Education

The purpose of the study was to assess knowledge, awareness, attitude, and beliefs of preservice teachers toward environmental education. The participants for this study were twenty-six preservice teachers enrolled in science method for teachers' course. Pre-and post-environmental education content knowledge tests based on interactive virtual activities were used to assess environmental education content knowledge. Pre-and post-Environmental Education Awareness Survey (EEAS) assessed awareness, attitude, and beliefs toward environmental education. The overall results indicated that the preservice teachers improve their knowledge, awareness, and positive attitude, and beliefs toward environmental education and awareness activities. The study further recommended that environmental education must be introduced at the elementary school level.

Christina Siry Sara E. Wilmes

Supporting Elementary Teachers in Enacting Curricular Reform and Reform-based Science Instruction

Elementary science education has the potential to build on students' natural curiosities about their world, promote scientific literacy, and foster positive science identity development. When science is taught with reform-oriented methods such as phenomenon-based inquiry, it can promote equitable science learning opportunities for students as they see themselves as knowers and doers of science. However, these methods are not intuitive for many teachers, and few professional development opportunities for elementary teachers of science. This related paper set, including three studies from across the U.S. and one from Europe, considers the affordances of curricular infrastructure-construed broadly to include curriculum, curriculum materials, and standards--as boundary objects to support the professional learning of elementary teachers towards enacting more reform-oriented science teaching methods. In each paper, teachers engaged with these boundary objects in collaboration with partners to transform aspects of their science teaching and professional identities. With limited opportunities for professional learning for elementary teachers of science, it is imperative

that the field continues to grow in our understanding of how to make a difference in their science teaching practices, and the papers in this set each bring a different and critical lens to this challenge.

Sam Skrob-Martin Alicia Batailles

"Do worms have urine?": Resources students draw upon in response to uncertainty in biology laboratories

There have been recent calls in educational reforms for students to participate in the ways of feeling, thinking, and doing that scientists do to explore biological phenomena (AAAS, 2011). One way of students authentically participating in the scientific discipline is to wrestle with uncertainty, which is an aspect of scientists' work that is ambiguous or non-obvious (Manz, 2016). As students work through this uncertainty, they will pull on different resources, both from their everyday knowledge and from course materials, to make sense of the problem they are working through. This study seeks to understand the resources that students draw upon in the wake of problematizing, or identifying and motivating an unknown, in the wake of scientific uncertainty. We examined students' wrestling with different types of scientific uncertainty and paid attention to the resources they drew upon. Implications for this work will be discussed.

Kyla Smith Judith Hillier

A Physics Case Study for Why Teachers Feel In- or Out-of-Field: Looking Beyond Educational Background

Out-of-field teaching has been shown to have negative effects on student achievement, students' decisions around future studies, and the instructional strategies used to support their learning. Behind these challenges for students are teachers working to overcome challenges of their own: teaching out-of-field negatively impacts teachers' wellbeing and retention in the profession. This study investigates out-of-field teaching within high school sciences and mathematics. A theoretical framework of social cognitive theory places teachers' voices at the centre of the study, and this agentic theory acts in opposition to the lack of control teachers typically have over what they are assigned to teach. In alignment with this theory, teachers identify their own status as in- or out-of-field, including three possible gradations of out-of-field. The study uses a questionnaire and interviews to engage with teachers of grades 9 through 12 sciences and mathematics in the four western provinces of Canada. This paper presents qualitative findings from teachers of physics participating in the questionnaire phase of the study. While one's status as teaching out-of-field is commonly defined and determined in relation to their educational background, these findings suggest that teachers may feel in- or out-of-field for several additional reasons.

Alex J Sobotka Ben A Janney

University Biology Students' Sociocultural and NOS Associated Positions About Policymakers' and Scientists' COVID-19 Responses

Like with all SSI, engagement with the COVID-19 pandemic requires consideration of scientific (e.g., NOS) and non-scientific (e.g., social, cultural, political, and economic) factors. Complicating matters, the emergent and revisionary nature of COVID-19 science, aptly described as "science-in-the-making", has been leveraged by certain groups in a manner that undermines peoples' trust in evidence-based COVID-19 mitigating policy and decision-making. This thematic analysis demonstrates the nuanced ways of how 475 university biology students used and prioritized NOS conceptions and sociocultural considerations when providing positions about the appropriateness of policymakers' and scientists' COVID-19 responses. Salient findings include that the students' political group affiliation associated with how they justified their positions through scientific (e.g. nature of COVID-19 science) and non-scientific (personal liberty and economic impacts) considerations. For instance, while students across political orientation groups referred to the emergent and revisionary nature of COVID-19 science in their justifications, the presence of this NOS aspect and the extent it was portrayed negatively or positively associated with the students' political affiliation. This work highlights the importance of teaching science in a manner that promotes functional scientific literacy among students through recognizing how NOS and sociocultural factors influence SSI engagement.

Daniel Ayomide Solarin Peter A. Okebukola

Will the Culturo-Techno-Contextual Approach Help Students' Understanding of Difficult Concepts in Computer Studies?

This study is a two-phase study (Survey and Experimental phase). The survey phase entails the researcher interviewing the students on difficult topics that led to poor academic achievement in Computer studies in which Python programming was mentioned, different teaching methods have been deployed by teachers to teach python programming and other difficult topics over the years, yet the result has not been encouraging as students underperformed. This study adopted the mixed method design to determine the efficacy of the Culturo-Techno Contextual Approach (CTCA) in breaking difficulties related to python programming as a difficult concept in the Nigerian Computer Science Education Curriculum. A total of 94 senior high school students studying computer science education participated in the study. The experimental group (N=41) were taught using CTCA while the control group (N=53) were taught using the traditional method. The Python programming Achievement Test contains 40 items used to collect data. Analysis of covariance procedure was applied on the data with pretest scores inserted as the covariate. The results showed that the experimental group significantly outperformed the control group [F (1,89) = 16.89; p<0.05]. This study has been able to make learning of science easy for students through the use of CTCA.

Regina Soobard Ana Valdmann

Teacher's Readiness to Promote Science-related Career Awareness Among Middle School Students

The aim of the study was to determine science teachers' readiness to use scenarios in their teaching to develop middle school student's science-related career awareness, as a component of scientific literacy.

In the first stage, teachers' readiness was investigated qualitatively, using five purposefully developed contextual scenarios, each introducing at least two sciences-related careers. In this stage, after examining all 5 scenarios, 10 teachers participated and answered 5 open-ended questions plus one question related to scientific literacy in general. In a second stage, teachers' readiness was investigated quantitatively, using a purposefully developed questionnaire based on an extensive literature review, determining readiness to make changes in teaching. In this stage, 300 teachers participated. The results of the qualitative analysis showed that teachers' readiness to use scenarios differed and even an experienced teacher needed versatile guidance to develop career awareness as one aspect of science literacy. While outcomes from the qualitative stage are elaborated in this proposal, results from the quantitative stage are to be discussed during the NARST 2022 conference.

Ornit Spektor-Levy Netta Perry

Inspiring Learning Environments—What Preschoolers' Prefer? Do Enriched Environments Enhance Engineering Capabilities? Does Gender Matter?

One way to enhance children's engagement with STEM is by designing learning environments that offer rich opportunities for exploration and construction. This study examined (a) preschoolers' (5-6 years) preferences in the learning environment; (b) to what extent free play in a learning environment enriched with constructional materials enhances engineering thinking; and (c) whether gender matters. In order to examine preschoolers' (n=198) preferences, we developed the Photograph-Interview with Children (PIC). Most preschoolers favored the Construction Center (mainly boys) and the Home-Themed Role Play Center (mainly girls). Next, 228 preschoolers participated in an intervention study. The intervention group (n=126) experienced 6 months of enriched learning environment that encouraged constructional free play. All participants were assigned a pre- and post- problem-solving construction task—The Bridge. Video micro-analysis revealed indications of six-EHoM according to Lucas, et al. (2014). Boys scored higher. Intervention and comparison groups significantly increased their scores on the total-EHoM and on the problem-finding and visualizing at post-test compared to pre-test. However, the effect sizes were greater among the intervention group and girls. Our evidence shows that when educators allow children to function independently in an educational environment richly equipped with appropriate materials and tools, the children improve their engineering practices.

Jeffrey Spencer Danielle N Maxwell

Using environmental chemistry to engage students in scientific thinking while affirming their cultural context

Science education often portrays content from the perspective of traditional Western academic perspectives. As a result, non-majority students may struggle to relate material learned in class to their lived experiences and culture. Cultural relevance is gaining momentum in education reform movements, relating content in the classroom to students' cultures and worldviews. Even with this momentum, examples of implementing culturally relevant instruction remain sparse in postsecondary chemistry. This presentation outlines a collaborative effort to explore how culture and context influence the design and

implementation of culturally relevant curricular materials for introductory chemistry. Throughout the ongoing process, students work with community members, Elders, and scientists to engage in an environmental chemistry research project focused on integrating local, traditional, and scientific resources to explore Arctic snow processes. We outline the design considerations used to construct and implement a culturally relevant chemistry unit and describe activities where students cultivated relationships with the community and identified resources to inform their research design and interactions in the classroom. We also detail how culturally relevant education relates to the unit and identify areas where we are still growing as we engage in the design process.

Caroline T. Spurgin Alexandra I. Race

Patchworking Critical and Cultural-Historical Activity Theoretical Analytics for Research in Science Education

In this theoretical paper, the authors each illustrate a critical CHAT analytic framework that she "patchworked" together in order to make sense of learning in a science teacher preparation program (Higgins, Madden, Berard, Lenz Kothe, and Nordstrom, 2017). [Author's] work centers Science Teacher Candidate (STC) learning as a cultural-historical phenomenon, material-Discursively situated, and shot through with power (Vygotsky, 1986; Bazzul, Tolbert, Kayumova, 2019; Moje and Lewis, 2007). In studying this phenomenon, [Author] patchworked analytics from CHAT, feminist science studies, critical sociolinguistics, and case study design (Creswell, 2014) to develop an analytic method called Critical Discursive Activity Analysis (CDAA). [The other author] presents a framework that combines Critical ethnography and CHAT (Langemeyer & Roth, 2006), called Critical Ethnographic CHAT (CE-CHAT), that facilitates equity-driven, praxis-centered research which destabilizes power, engages in multi-sited sensibilities, and uses an intersectional analysis to dialectically explore how science education can be repositioned for expansive, community-focused learning. We share our original analytic frames in hope of ultimately expanding possibilities for multispecies flourishing, to caring for/in/with our human and more-than-human kin, and more just and lovely futures (Haraway, 2016; Kimmerer, 2013).

Caroline T. Spurgin Sara Tolbert

Talking beyond science: Deconstructing whiteness and hegemonic language ideologies in preservice science teacher education

This related paper set draws on raciolinguistic perspectives to raise new questions about racialization, language, and power in science education research, pedagogy, and teacher education. Each paper draws on recent scholarship from Jonathan Rosa and Nelson Flores to shift the gaze from the linguistic practices of racialized speakers (e.g., are minoritized students acquiring 'scientific language'?) onto the professionalized practices of the listening subject (e.g., how are teachers expected to arbitrate who is speaking or writing 'like a scientist'?). The first three papers turn scrutiny onto prevailing modes of perception in U.S. science education. Through analysis of science teacher surveys, language expectations in science course materials, and pre-service teacher interviews and small group discussions, these papers illustrate exclusionary processes of linguistic authentication, racializing appraisals of disciplinary

legibility, and the typologizing of who is identified/identifiable as 'talking science.' The fourth paper situates these patterns in historical perspective by examining how similar raciolinguistic distinctions took shape in the segregated science instruction offered to Mexican American students a century prior. Together, the papers interrogate foundational assumptions shaping the White-perceived listening subject of U.S. science education to open a more robust dialogue concerning linguistic and racial justice in the field.

Alex T. St. Louis Hayat Hokayam

Comparing Undergraduates NOS Views in Traditional vs. Inquiry-Taught Science Course

Two primary pedagogical teaching styles for science content include lecture and inquiry-based learning. This qualitative study analyzes the views about NOS between students enrolled in a traditional lecture and laboratory course and an inquiry-based laboratory course, in addition to comparing inquiry-based student views to the scientist who taught them. Undergraduate students enrolled in the traditional (Section TR) and inquiry-based (Section IQ) course was administered Views of Nature of Science Form C (VNOS-C) (Lederman et al., 2002) to measure their views after partaking in two different pedagogical-styled courses. We report on two aspects of VNOS-C: definition/explanation of science and role of creativity and imagination within the scientific process. The data shows that Section IQ held slightly more concrete views of creativity and imagination in science and more informed views of science, possibly through taking an inquiry-based course. In addition, Section IQ held similar NOS views to the scientist. This study shows that even if you teach inquiry as means (Abd-El-Khalick et al., 2004), students can form transitional or even informed views of the roles of imagination and creativity in the scientific endeavor.

Molly M. Staggs Karl G. Jung

Teacher Understanding of Funds of Knowledge in the High School Biology Classroom

Emergent bilingual (EB) students bring to the science classroom a variety of cultural and personal experiences that are frequently known as funds of knowledge (FoK). Previous studies have shown that when teachers connect their science instruction to EB students' FoK, student interest and engagement are improved, and students are able to see science as relevant to their lives. This study investigates the ways in which teachers conceptually understood FoK after completing a professional development module on funds of knowledge as part of their participation in a larger NSF-funded project. Findings revealed that teachers understood funds of knowledge to be the incorporation of student interests and lived experiences in their science instruction. Teachers found it challenging to incorporate students' FoK in a classroom where one student's FoK may not be relevant to all students, but percieved that the use of FoK in their instruction was beneficial to students in several ways including increasing student engagement and building student-teacher relationships. These findings speak to the importance of educating teachers on funds of knowledge and how to use them in the science classroom.

Reut Stahi-Hitin Alexandra Moormann

Evolution Education in Light of the Conception of Religious Science Teachers and Scientists towards Evolution and Religion

Many people not only lack an understanding of evolutionary concepts but also resist accepting the theory of evolution as the best scientific explanation. Factors affecting the development of understanding and acceptance are diverse, including cognitive, affective, and contextual features. Religious identity and background are often negatively related to acceptance rates and are among the main factors for predicting whether people will accept or reject the theory of evolution. To contribute to this ongoing challenge that peoples' religious identity brings into evolution education, this related paper set combines four papers that focus on the interplay of religious identity with evolution acceptance. In the first paper, historical data were investigated to determine if acceptance patterns have changed over time based on students' religious affiliation. The second paper determined the influence of culturally competent practices on students' evolution acceptance outcomes. The authors of the third paper gathered evidence through in-depth interviews to better understand conceptions of religious people but who accept the theory of evolution. In the fourth and last paper, responses of self-identified creationists to often-used evolution acceptance measurements were collected to generate new validity evidence.

Hanna Stammes Ineke Henze

Capturing a Teacher's Multidimensional and Dynamic Attention to Student Learning in Design-Based Chemistry Education

In this study, we explored the multidimensionality and dynamicity of teacher attention to student learning in design-based chemistry education. Design-based science education is known for its potential to promote a range of aspects of student learning. Leveraging this potential does, however, require teachers to pay close attention to learning in the course of instruction. Even though this ability has been posited as especially important yet complex in the multifaceted, open-ended context of design (Watkins et al., 2018), we still know little about teachers' attention in secondary school, design-based science contexts. By engaging an experienced chemistry teacher in reflection conversations in a formative assessment environment we sought to gain insight in the nature of attention in a design-based science context. Findings demonstrate that attending to student learning in this setting can entail attending to aspects of learning typically classified as disciplinary (e.g. chemical thinking, design practices), as well as to aspects of learning deemed more generally relevant (e.g. social interactions, emotion). Moreover, we found that attention within certain aspects of learning varied during a design-based project and reflection conversations, while attention to other aspects remained stable. Findings and implications for future research in this emerging area of study are discussed.

David P. Steele Sophia Jeong

Secondary Pre-service Teachers Becomings: Fostering Anti-deficit Noticing Through Attending To Students' Sense-making Repertoires

This related paper set responds to calls for re-imagining disciplinary learning in science (Warren et al., 2020) and "broadening participation" in STEM (NSF Includes, 2019). Specifically, the papers in this session will explore practices such as anti-deficit noticing as ways to support equitable science teaching and learning. Deficit ideologies can lead researchers and educators to blame students for perceived deficiencies in school rather than attending to the social structures that limit students' opportunities for learning (Peck, 2020; Philip, 2011). Anti-deficit noticing (Louie et al., 2021) is a teaching practice that explicitly challenges these deficit ideologies by (1) identifying deficit frames that limit students' opportunities for learning and (2) shifting toward anti-deficit frames that empower minoritized students. While anti-deficit noticing is becoming increasingly prominent in math education (Louie et al., 2021), less is known about how this practice can be supported in science education. In response, this session will offer an illustrative example of anti-deficit noticing in a secondary science classroom, and it will explore anti-deficit approaches to preservice teacher education and in-service teacher professional development.

Jaymie Paige Stein John Craven

Relationships Among Teacher Beliefs About STEAM Education, Perceptions of School Climate, and Enacted Practices.

This study explored the relationships among teacher beliefs regarding a science/technology/engineering/arts/mathematics (STEAM) approach to teaching, teacher perceptions of the school climate relative to creativity and innovation, and enacted practices in STEAM-focused education. Eighty teachers (N=80) across middle and high school classrooms in schools within the large, urban region in the Northeast USA promoting STEAM education were surveyed. Climate, Creativity Climate, Teaching Efficacy, STEAM Awareness, 21st Century Skills Implementation, 21st Century Skills Beliefs on STEAM Curriculum Beliefs were statistically significant, F (7, 57) = 8.854, p < .001, with the Bonferroni correction representing a = .025 (i.e., .05/2 multiple regressions = .025). The R was .72 and R2 was .52 representing a substantial relationship between the seven independent variables and STEAM Curriculum Beliefs. The R2adj was .46 indicating a smaller adjusted R2 than the unadjusted R2 suggesting that not all independent variables were contributing to predicting STEAM Curriculum Beliefs. The standard error of estimate (SEE) was 0.48 indicating a fairly accurate prediction of STEAM Curriculum Beliefs.

Pnina Steinberger Yovav Eshet

"I'm too slow to get through Statistics": The Relationship between Statistics Anxiety and Academic Dishonesty

The current research examines the impact of Statistics Anxiety on Academic Dishonesty as manifesting in undergraduate social science students attending introductory statistics courses in different learning environments: Covid-19-Emergency Remote Teaching (ERT), Planned Online Environment (POE), and Face-to-Face (F2F). Data were collected from 291 students in academic institutions studying for a

bachelor's degree in the social sciences. Structural Equation Modeling (SEM) was used to examine the relationship between students' previous academic achievements and Academic Dishonesty mediated by Statistics Anxiety. The results of the multi-group analysis show that path coefficients differ between the three learning environments (POE, F2F, and ERT). Specifically, the results support a model in which previous math and academic achievements are significantly related to Academic Dishonesty mediated by Statistics Anxiety in POE environments only. Accordingly, POE statistics learning is less effective than F2F instruction and practice. Our research shows that instructors' presence in the learning process reduces both students' anxiety levels and unethical behavior. Thus, we recommend that in POEs, instructors' presences include supportive, emphatic, and interpersonal interaction to reduce virtual distance. We conclude that introductory courses in statistics be compatible with the needs of students experiencing Statistics Anxiety for a better sustainable statistical literacy.

Lynn Stephens Steve Roderick

Leveraging causal heuristics to scaffold student understanding in dynamic system models

The science education community acknowledges the importance of integrating learning about complex systems and adopting a system thinking approach as part of the effort to prepare scientifically literate citizens. However, accumulating research in the past years has clearly shown that teachers and students alike face various challenges engaging in aspects of system thinking. One of the prominent challenges includes the difficulty of addressing underlying mechanisms that account for a system's behavior. In this paper set, an international effort is made to present different tools and strategies that can serve to elicit some of the underlying mechanistic reasoning teachers and students use to make sense of complex systems. We show how system dynamics models, agent-based models, and concept maps can be used to elicit students' mechanistic reasoning and support it. Our collaborative work provides an opportunity to learn about different tools and the affordances they provide, both for characterizing mechanistic reasoning in the context of complex systems, and supporting teachers and students in making sense of complex phenomena using system thinking aspects.

Fabian Gabriel Sterzing Christoph Kulgemeyer

Learning Effective Explanation Videos in Physics Lessons

Explanation videos are increasingly important for science education. However, it is still an open question how (or even if) explanation videos influence students' achievement effectively. In the literature on the learning effectiveness of explanation videos, two major topics can be identified: The quality of the explanation videos and their integration into the learning process. The goal of the present study is to research how (a) the quality of explanation videos and (b) the instructional setting can be varied to support conceptual understanding and the quality of students' actions in practical tasks. An experimental study (pre-post design) was conducted (N=142). Despite a short intervention time, our study shows high learning gains in conceptual and declarative knowledge on practical tasks. However, we could not confirm that the learning gains depend on the quality of the explanation videos or on the learning environment in which the video appears. However, students with lower pre-knowledge tend to

learn from explanation videos than those with high pre-test results. This "inverted Matthew effect" could be interesting for science education.

Kimberly Carroll Steward Cory T. Forbes

Teachers' Use and Adaptation of a Model-based Climate Curriculum: A Three-year Longitudinal Study

Foregrounding climate education in formal science learning environments provides students opportunities to develop critical climate-related knowledge and skills. However, research has shown many challenges to teaching and learning about Earth's climate and global climate change (GCC; Bhattacharya et al., 2020; 2021), including how teachers cultivate climate-focused learning experiences. This longitudinal study aims to establish how secondary science teachers learn, over time, to use a model-based climate curriculum to support students' learning about Earth's climate and GCC. We employ a concurrent mixed method, multiple-case study approach and collected multiple lines of data, including teacher interviews, classroom observations, and daily reflections, to address two research questions,1) how do two secondary science teachers implement a model-based curriculum? and 2) how do the teachers' implementation strategies evolve over the three-year study? Our findings show that significant differences were identified between teachers and curriculum, between years, and within the interactions of teachers and the years. Both teachers engaged in increasingly model-centric practices, although teachers' observed practices were less model-centric than the provided curriculum. Study findings contribute to the growing research literature within climate education by providing insight on how teachers implement model-based climate curriculum and how these strategies evolve over time.

Lisa Stinken-Rösner

Fostering TPACK in Science Teacher Education – Re-Design and Evaluation of a University Course

STEM education has, due to its technology-related topics, many potentials for a multifaced use of technology (ICT). Integrating ICT into the classroom requires (pre-service) teachers to develop additional knowledge about the technologies themselves and their purposeful implementation in practice. In contrast to approaches that treat ICT as add-on, ICT was integrated systematically into the existing study program at the University of X following the transformative TPACK view (e.g., Mishra & Koehler, 2006). Thus, fundamental science education topics are linked explicitly with the purposeful application of technology in practice. The designed course has a (significantly) positive influence on students' behavioral orientations (TPB; Ajzen, 1991) and self-reported professional knowledge (TPACK; Koehler et al., 2014). Additionally, content analysis of lesson plans showed that after attending the course, preservice teachers are able to design multimedia enriched learning situations, which go beyond the mere substitution of "classical" media (SAMR; Puentedura, 2006) and foster students' cognitive engagement (ICAP; Chi & Wylie, 2014).

Annabel J Stoler Eve Manz

Developing Routines for Planning Elementary Science Investigations

This poster describes the development of an instructional routine that supports elementary-aged students in planning scientific investigations. This work is situated within a larger design-based research project focusing on uncertainty in elementary school science. One goal of this work is to develop tools for teachers that support them in incorporating uncertainty into their classrooms. This poster outlines the development of a routine that can be used to design lessons that support students in planning an investigation. In order to develop this tool, we used qualitative analysis from video footage in 2nd and 5th-grade classrooms to identify routine components and teacher moves that elicited productive student talk. This project supports an understanding of how teachers can support students' epistemic work, and it contributes to the literature by addressing the lack of research on planning investigations in elementary classrooms. The analytic process introduces a principled approach to using empirical research to develop practitioner resources.

Regina Suriel Alejandro J. Gallard

Latinx Science Learners and Scientific Literacy: Successes and Challenges

Latinx science learners in the United States face different challenges that prevent them from fully engaging in rigorous STEM curricula, thus limiting their development of scientific literacy and proficiency. Historically, national, local and classroom level measures painfully show achievement gaps among Latinxs and their White/Asian counterparts. From this "objective" angle, science underperformance results from challenges directly linked to socio political agendas that support deficit perspectives and are enacted through educational policies and curriculum that hamper the cultural and linguistic richness Latinx's bring with them. As such, Latinx science learners are often shunned away from fully engaging in science learning. To gain the trust of the Latinx community, science educators must unite to defy and change beliefs, perspectives and the curriculum and embrace the funds of knowledge Latinx's inherit and are eager to share with peers and more knowledgeable others. Since its inception, LARIG continues to serve as a safe space for Latinx members and friends. However, each year we extend our invitation for others to join us. Through this panel discussion, we provide a forum for critical dialogue on the successes and challenges of Latinos in science education, so that we can better inform interested NARST members and grow our community. Moreover, our discussions seek to unite us for a common goal- increasing global scientific literacy, proficiency and promoting unity and inclusion in science and science education. We are thrilled to have six national and international panelists who will discuss their research on the aforementioned themes (see list below). Research themes have also been arranged to address different levels of education, from K-22.

Anshuman Swain Marcia Shofner

Exploring the Impact of Peer-to-Peer Interactions on Learning and Course Performance in an Online Environment

This study explores the relationship between peer-to-peer interactions, students' group formation, choice of research, and course performance in an online asynchronous ecology course in a research university. Peer-to-peer interactions have been known to enhance learning experience for students in a wide array of contexts, including online courses. However, there is less research on how these interactions shape the performance and interests of students over the timeline of a course. We used data collected from a medium-sized ecology course, that required intense discussions and peer interactions, over four semesters with the same instructor, teaching assistant, and course structure. Using tools from network science and other statistical analyses, we find that peer interactions were not only associated with student performance, but also shaped their future interactions (e.g., working group formation), and interests (e.g., choice of course research topic). We provide here data analysis techniques that could be used by others for further explorations of the importance of incorporating peer-to-peer interactions in online and in-person classes. We believe that using such data analysis techniques during the duration of a course could help instructors in planning the course structure to promote students' collaboration and success in the course.

Awais Syed Dennis Lee

Uncovering Sex and Gender Language in High School Biology Textbooks

This study explores how high school biology texts might contribute to gender disparities by reinforcing the belief that science ability is innate. A sample of six high school biology textbooks was analyzed to uncover how often sex and/or gender terminology are used in human genetics chapters and what traits are associated with the terms, how the within and between-group variability in human traits are described, and what types of causal factors are used to explain variation between groups. About one-third of the paragraphs included sex and/or gender terms. Texts associated gender and/or sex most often with genetic and morphological traits and rarely with behavioral, cognitive, hormonal, or neurological traits. Texts most often discussed sex and/or gender groups as being uniform and when texts did describe differences within a group, these differences were often portrayed as being typological in nature rather than continuous. Further, results suggest that genetics texts discussed differences between sex and/or gender groups more often than similarities and often used internal factors to explain similarities and differences between sex/gender groups. Findings from this study have implications for how instructional materials attend to the constructs of sex and gender in high school biology.

Mariam Takkouch Isha DeCoito

Are School Gardens Culturally Relevant? Forging Connections Between High School Students and the Community

This paper explores the role of school gardens, as an informal outdoor educational setting, in fostering connections between high school students and the community. This proposal focuses on a social justice framework and the extent to which this is addressed through the school gardens by addressing the following research questions: a) What effect, if any, do school gardens have on high school students'

social justice awareness and community building skills? and b) If, and to what extent, are school gardens culturally relevant to the students? The study utilized a mixed-method design, specifically a case study method. The setting for this case study was an urban high school in Canada that maintained a garden on the school grounds. The participants included 23 high school students, eight teachers, one principal, and two volunteers. The primary sources of data for this paper were classroom/school garden observations and semi-structured interviews with teachers and students. Findings show the positive impact of the school garden activities on students' awareness related to social justice and community building. Furthermore, the school garden activities were linked to students' cultural backgrounds, indicating that they can help teachers provide culturally relevant instruction for their students.

Rachel Takriti Hassan H. Tairab

Adaptation and Validation of a Questionnaire for Measuring Teachers' Views on Nature of Science.

Nature of science (NOS) has been a curriculum goal in science education for several decades. Teachers' views of nature of science (NOS) play an important role in how they teach science and consequently affect their students' understanding. Current estimates of 422 million Arabic speakers worldwide indicate the need for assessment tools to be available in Arabic. This paper reports the adaptation and validation of a questionnaire to measure Arabic-speaking teachers' views of NOS. The Reconceptualised Family Resemblance Approach to Nature of Science questionnaire (RFNQ) is increasingly used to assess fundamental views and understanding of NOS. This paper reports the process of adapting and validating an Arabic language version of the RFNQ to produce the RFNQ-AR. A sample of 130 pre-service teachers completed the RFNQ-AR resulting in a reliability of α = 0.89 for the measure as a whole, with sub-scales varying from 0.72 to 0.74. The RFNQ-AR can be used to facilitate research into teacher understanding of NOS and enable evidence based training in this area to ensure optimal student performance. Given the psychometric properties of the RFNQ-AR, it is considered to be an appropriate tool for this purpose.

Tali Tal Gail Richmond

The role of context in supporting responsive place-based urban science teaching

In the U.S. recent widespread adoption of the Next Generation Science Standards (NGSS) has required deeper knowledge and different instructional practices from all teachers. The ability to take up NGSS-aligned practices is particularly challenging in under-resourced urban school contexts. Our work has centered on developing sustainable partnerships between teachers and informal science educators (ISErs) to support deeper understanding of how to provide outdoor experiences which are NGSS-aligned and teaching that is specific to their place and the cultural and social needs of their students, making use of several frameworks, including place-based, design-based implementation research, culturally responsive teaching and heads-on, hands-on, hearts-on (3H). In this related paper set, we consider the work ISErs do with other educators, students, and the general public, and how these contribute to their identity (Paper1); evaluate theoretical frameworks as interpretive lenses on such partnerships (Paper2); address how we made use of a virtual environment to establish professional community and "set the stage" for summer and school-year learning (Paper3); investigate the program's impact on teachers

questioning and subsequent planning intentions (Paper4); address how specific contextual factors shaped the ways the program was taken up and our leveraging of these factors to support participant learning (Paper5).

Giulia Tasquier Erik Knain

EQUIPPING THE YOUNG TO TACKLE CURRENT SOCIETAL CHALLENGES

The global emergence of youth movements concerning climate change demonstrates young people's engagement with societal challenges that involve science in complex ways and have an impact on their present and future. Dealing with the threatening challenges and profound changes that characterise our era requires the development of knowledge and skills to navigate the uncertainty and complexity of science as part of society and everyday life. How can we support school students in transforming the base of knowledge and experiences to face the ongoing crises and contribute as individuals and active participants in democratic society to enable the required transformation? We address this broader question through a study framed within the project [ANONYMISED], aimed at promoting new forms of scientific literacy and skills to empower students to become agents of change. In [ANONYMISED] project, school science is conceived as involving learning and transformation across three spheres—practical, political and personal—where both individuals and their institutional contexts change as participants gain agency over their learning processes. In this paper, we illustrate this approach and present the preliminary analysis of a first pilot iteration which show the kind of individual/collective dynamic that the project's transformative activities afford.

Lezly Taylor Brenda R. Brand

Navigating Sociocultural Constraints that Influence African American Students' Participation in STEM: Deconstructing STEM Access

National imperatives to broaden STEM participation for underrepresented groups remains a prominent priority across educational research. Due to marginal effectiveness associated with racialized minorities, researchers continue to explore factors deemed significant to influencing their participation. Researchers have discussed dispositional factors such as identity and self-efficacy as influential to racialized minority students' participation and persistence in STEM; however, there is a continued need to identify how these dispositional factors are influenced through program structure, and their alignment with the needs of students. Museus and colleagues (2011) summarized five key implications for effective STEM programs: funding to replicate effective projects, peer collaboration, collective classroom cultures, encouraging students' beliefs, creating relevant experiences for STEM career awareness. These implications were considered in the design of the Actualizing STEM Potential in the Mississippi Delta (ASP) project, a pre-engineering afterschool robotics program with the goal to enhance the identity and self-efficacy of African American students and to uncover the significance of focusing on these dispositional factors for marginalized students. Findings for this longitudinal mixed methods case study evidence an increase in identity and efficacy extending the definition of access to an

environment that counters the socialized impairments that dissuade marginalized students' participation in STEM.

Stephanie Teeter

Examining Practices and Attitudes about the NSF's Broader Impacts Criterion: A Systematic Literature Review

Since its inception, the National Science Foundation (NSF) has been a key source of funding for scientific research. Increasing focus on potential societal benefits has led proposals to the NSF to be evaluated on two criteria: Intellectual Merit and Broader Impact. Broader Impact describes the potential for a research project to benefit society or advance one or more of the desired societal outcomes enumerated by the NSF. These outcomes include benefitting society at large, broadening participation of underrepresented groups in science, technology, engineering, and mathematics (STEM), and enhancing public understanding of STEM topics. Despite the broad range of what qualifies as Broader Impacts, one of the most often proposed types of activities is to work with students and teachers to create educational content, which makes Broader Impacts criterion remains poorly understood and undervalued by applicants and reviewers alike. This systematic literature review sought to explore scientists' perceptions of and practices surrounding the Broader Impacts criterion. Findings also include best practices for ideating and implementing activities and barriers that have historically and still prevent scientists from truly embracing Broader Impacts.

Maria E. Tellez-Acosta Scott McDonald

That's Enough For An Explanation: Pre-Service Teachers Linking Epistemic And Pedagogical Decisions When Developing Models

For this study, we re-designed a pedagogy to support pre-service teachers in making decisions about developing explanatory models when using online content videos. Pre-service teachers' use of these resources for their professional learning has increased. Yet, this work requires an effortful practice to purposefully plan modeling-based investigations. This study aims to characterize what criteria pre-service teachers consider to make these decisions and the role of these criteria in the negotiation of meanings around the pedagogy they enacted. By analyzing the discourses of two groups of elementary pre-service teachers using the professional vision framework, we characterized twelve criteria regarding the use, construction, evaluation, and revision of models/explanations. We also found that these criteria played out two different ways. The considered criteria depended on the groups prioritizing the epistemic or pedagogical goals of their decisions. These findings have an important implication in supporting pre-service teachers developing professional expertise in planning modeling-based investigations. When pre-service teachers are supported to discuss specific features of the models/explanations development, they can generate criteria based on their proposed goals. They have the opportunity to strengthen their practice by linking epistemic and pedagogical decisions in planning to engage and support students in developing explanatory models.

Moonika Teppo Regina Soobard

An Investigation of Teaching and Learning Approaches Influencing Students' Intrinsic Motivation towards Science Learning: A Longitudinal Analysis from Grade 6 to 9

Research findings have indicated that going from primary to secondary school involves changes in science teaching and learning. However, there is a lack of longitudinal studies investigating students' intrinsic motivation towards science learning in transiting from one school level to another. The main aim of the current study is to examine the factors that predict lower secondary school students' intrinsic motivation towards science learning from grades 6 to 9. Data collected, as a part of a longitudinal study, in 2016 and 2019 is used for the current study. Using a previously developed instrument, linear regression analysis is used to find out how the frequency of the use of different teaching and learning approaches influence students' intrinsic motivation towards science learning. Results indicate that in both grades, the perceived frequency of using traditional approaches predict, in a significantly positive way, students' feeling of interest, competence, autonomy, effort and value towards science learning. In addition, the results show the decline in students' intrinsic motivation with age. Further suggestions and implications for practice are discussed.

Stephen L. Thompson Amber Adgerson

Examining Virtual Rehearsals and Practice Science Teaching as Support Systems for Rural Elementary Teacher Residents

Elementary preservice teachers frequently gain theoretical knowledge about science teaching from their teacher preparation programs but do not have many opportunities to practice, and gain confidence using, their newly learned pedagogical knowledge in authentic contexts. One promising response, called rehearsals, is currently being incorporated in science and mathematics methods courses to provide preservice teachers with practice-based opportunities. Through rehearsals, methods students enact specific instructional practices while the instructor and classmates role-play student learners. This study focused on how virtual rehearsals and collaborative practice teaching, reflection, and mentoring during an initial summer institute impacted rural elementary Teacher Residents' perceptions of their pedagogical knowledge and content knowledge. The research team used a mixed methods study design that included field notes, interviews, focus groups, and surveys. Key findings reveal that Teacher Residents developed knowledge of teaching strategies by practicing, and that the teaching practice helped them gain confidence. They also valued the safe professional spaces created by the summer institute and the co-learning with Coaching Teachers that occurred. The initial interactions during the summer institute; co-planning lessons, enacting them with support, and reflecting on them postengagement, were also viewed as important to the Teacher Resident/Coaching Teacher power structure and collaborative relationships.

Preethi Titu Seema Rivera

Science Preservice Teachers' Views on Diversity and Race in the Science Classroom

Research addressing equitable science teaching and practices is expanding. However, comparatively little attention has been given to preservice teachers' studies and their views toward diversity and race. If we want to prepare these preservice teachers for diverse classrooms, we must first understand their views. Researchers have ascertained that teachers can work effectively with students differing from their own culture (Hawk, Cowley, Hill, & Sutherland, 2002) when they can relate to them and support their identity and learning as cultural beings (Hawk et al., 2002). The purpose of this case study was to explore the views of preservice science teachers toward diversity and race in their classroom. This study draws on critical race theory (CRT) (Ladson-Billings, 1998; Parsons, 2017) as the analytical lens to understand PST's developing capacities for promoting equity. Data were collected from discussion posts in online forums and written reflections based on course readings. The findings provide insight into science preservice teachers views on how diversity intersects with their teaching that are presented as two themes: a) Avoiding race b) Acknowledging cultural differences.

Mustafa S. Topcu Ayse Ciftci

Integrating Computational Thinking (CT) in STEM Education: Early Childhood Pre-Service Teachers' CT Teaching Self-Efficacy Beliefs

The purpose of the current study is to investigate the effect of Computational Thinking (CT) integrated STEM (Science, Technology, Engineering, Mathematics) approach on the early childhood pre-service teachers' CT teaching self-efficacy beliefs. Quasi-experimental design was used and a total of 68 preservice teachers participated in this study. While CT integrated STEM-based activities were carried out with the experimental group, STEM-based activities were carried out with the control group. The data of the study were collected through "the scale of self-efficacy beliefs towards teaching computational thinking" and the data were analysed by using independent samples t-test. As a result of the analysis of the data, it was determined that there was no statistically significant difference between the pre-test scores of the experimental and control groups regarding CT teaching self-efficacy beliefs, and that there was a significant difference between the post-test scores in favour of the experimental group. This reveals that CT integrated STEM education contributes more to the development of pre-service teachers' CT teaching self-efficacy beliefs compared to STEM education.

Gozde Tosun Amy V. Farris

Sensemaking Through Computational Thinking: Images of Computing as a Scientific Epistemic Practice in Teacher Learning

There is a growing need to articulate exemplars of scientific disciplinary learning that meaningfully engage computational thinking (CT) practices. We draw on literature from 48 professional development experiences for science teachers and preservice science teachers and characterize how CT is employed in science learning. At the top level, we find that CT is sometimes used as a way for students to report

final-form knowledge, a framing which fails to position computing as an epistemic tool. However, in other examples (17 of the 48 included in this analysis), computing is used for scientific epistemic aims, that is, learners use computational tools or principles towards sensemaking or investigation of scientific phenomena or concepts. This analysis is especially important because more sustainable efforts to engage students in CT in science class must support learners' epistemic practices in science, rather than merely teach something about CT. We review exemplars that illustrate how modest but powerful computing concepts can create points of entrée for further exploration of important science and engineering ideas. We contend that if teachers see that integrating CT can make science more learnable, then professional learning experiences about computing in science can have increased value towards epistemological goals in science education.

Hong H. Tran Yuxi Huang

Science Teaching Practices and Student Engagement in HyFlex Learning Environments

HyFlex (Hybrid-Flexible) is a course delivery method that allows students to choose whether to attend classes face-to-face or online. This course delivery method is gaining popularity. HyFlex environments offer the potential to promote equality, but also causes obstacles for science learning (Besser et al., 2020; Lynch & Baker, 2005). The present study describes science teaching and student engagement in HyFlex classes. The participants were 42 science teachers teaching at schools in the Southeast region of the U.S. The data came from weekly overview forms, interviews, and classroom artifacts regarding hundreds of lessons that were taught during the 2020-2021 academic year. The findings showed that the three most common activities teachers did during the lessons were assigning in-class work (e.g., read books, review learning materials, complete worksheets, take notes), lecturing, and facilitating whole-class discussion. The students did not often have opportunities to engage with the science and engineering practices. Most (78%) of the HyFlex science classes did not appear to involve modes of student engagement that enhance productive learning. Despite what was seen in the majority of lessons, it is possible to implement high-quality HyFlex science lessons because 22% of the lessons helped students engage constructively and/or interactively in their learning.

Khanh Q. Tran Selcen Guzey

Cultivating culturally sustaining STEM classrooms: A narrative inquiry case study of a science teacher

This narrative inquiry case study draws on culturally sustaining pedagogy and sociotransformative constructivism to understand the experiences of Ms. William in teaching diverse middle school STEM classrooms and to envision the possibilities of teaching STEM that is transformative and liberatory. We conducted semi-structured interviews and employed narrative analysis to identify narrative threads as Ms. William made meaning of her teaching experience. Our inquiry highlights the intentionality of a science teacher that aims to foster the assets of her culturally and linguistically diverse students. However, we found that her momentum in creating a student-focused classroom was thwarted by the contradictory obligations her school and colleagues reinforced. Therefore, key stakeholders must also feel the need to make classrooms student-focused and adept at recognizing, affirming, and cultivating

students of color's cultural wealth. As the number of young people of color in K-12 school increases, we must teach any subject with a multicultural lens that makes their learning more meaningful and engaging. We hope that the experiences of Ms. William inspire science teachers to achieve a vision for a science education that cultivates and sustains the cultural and linguistic assets young people bring to their science classrooms.

David F. Treagust Dewi Ungu

Comparative Analysis on the Impact of Scaffolding on Students' Interactions within Immersive Virtual Reality

This paper-set arises from recent research with 130 undergraduate students enrolled in Chemistry using immersive virtual reality (IVR). Students worked in pairs to investigate molecular structure, polarity, and intermolecular forces for simple and complex molecules. Investigations of students' interactions are based on video recordings, conversation transcripts, conceptual diagrams, and machine-generated location logs. Paper #1 presents an analytical framework of thirdspace to explain the dynamic transactions that take place in the students' physical environment, the designed virtual environment, and the experienced learning in IVR. Paper #2 focuses on how learning the same chemistry concept in different modes - physical magnetic model, computer simulation, and IVR application - afford different spatial explorations resulting in different patterns of spatial, conceptual, and social interactions during their learning experiences in IVR depending on the presence of the researcher's scaffolding. Paper #4 investigates changes in students' interactions within IVR as they experience three separate VR programs over a semester—water molecules and ice crystal formation, stereochemistry and taste receptor, and neurotransmitter and enzyme reaction. This related-paper set offers an insightful and productive way to investigate students' experiences, interactions, and chemistry learning within IVR.

Thomas R. Tretter Brian S Robinson

Investigating the Triple Threat of COVID-Necessitated Online Engineering Courses to Diverse Students' Sense of Belonging

The COVID pandemic forced many typical face-face classes to be shifted to online remote formats for the Fall 2020 semester, including the first-year engineering course at the focus of this study. Given that sense-of-belonging has been shown to be a predictor of university success, and that some groups of engineering students (underrepresented minorities, low-income, female) have reported weaker sense of belonging, we explored if the remote delivery of this first engineering course had additional negative consequences for these groups in the "COVID cohort" (Fall 2020), using the three prior pre-pandemic cohorts as historical comparison cohorts. This quantitative analysis found that: (1) COVID-necessitated remote teaching had more negative impact on sense of belonging for females but no difference for males; (2) there was no additional negative impact on sense-of-belonging for nonwhite students; and (3) high-income students had a reduced sense-of-belonging in the COVID cohort to the point where their sense of belonging was statistically similar to the low-income students. Since remote teaching formats

may become more common post-pandemic, it will be important for the field to consider how to avoid worsening the sense-of-belonging for diverse groups of engineering students so that inequitable access and opportunity for engineering success are not exacerbated.

Kathy Cabe Trundle Rita Hagevik

Empirical research on school garden-based learning: A systematic review of the literature

This study provides a systematic and comprehensive review of school garden-based learning (GBL) research from 1990-2019, with a goal of summarizing the current knowledge base and providing guidance for future curriculum development and research. This review reports the outcomes of 78 empirical studies that focused on GBL and science instruction and identifies trends in the research over time. The research studies included in this review help inform educators and researchers about potential benefits and limitations of GBL. Moreover, this body of research suggests important additional research questions and helps inform the design of future studies. The researchers identified three specific voids in the literature. First, no previous studies used a sequence of instructional activities and strategies or curricula that were widely available to teachers and researchers, which greatly limits broader implementation and the resulting overall impacts of GBL. Second, very few previous GBL research studies looked at the impact of garden based experiences over an extended period (i.e., multiple growing seasons). Finally, no previous studies proposed and tested a research-based, STEAM integrated model or curriculum for GBL. Designs of future studies should address these unmet needs.

Peggy J. Trygstad Sean Smith

Teaching Science During the COVID-19 Pandemic: A National Study of Teacher of Decision Making

COVID-19 has impacted nearly every aspect of life in the US and across the globe. This pandemic presents an example of why scientific literacy, conceptualized broadly to include science concepts, the nature of scientific evidence, and ideas about how science works, is so critical. We contend that it is essential for the spaces of science teaching and learning to be spaces in which complex issues like the COVID pandemic are explored. We contend that the science education community has a key role to play in supporting expanding dialogues and learning about critical societal issues particularly those, like the COVID crisis, which are so critically connected with science. This paper set features work from five research teams which took up the challenge of responding to the pandemic through science education. The researchers come together here to share some of the ways in which science education has been leveraged in the midst of the COVID crisis. The goal of the session is to surface what the science education community has learned through the current crisis, critical research directions that are needed, and how the community can position itself for effectively responding to the next global crisis that will inevitably emerge.

Ya-Ping Tsao Mei-Hung Chiu

Investigating a Chemistry Teacher's modeling-PCK in the Periodic Table Modeling-Based Instruction

The purpose of this study was to use modeling-based instruction to enable 10th grade students to construct knowledge of the periodic table through practice and to develop their modeling competence in science learning. The Modeling-Based Instruction (MBI) consisted of 11 50-minute classes and preand post- tests and interview before and after instruction. Classroom videos were used to track classroom activities and discussions, and videotape analyses were conducted to explore the impact of teacher performance on students' science concepts and modeling abilities. The results showed that modeling-based instruction can improve students' scientific concepts and modeling competence. More importantly, students showed significant improvement in modeling application. Furthermore, the effective MBI competence that the teacher equipped with includes four parts: The design of MBI, The knowledge of MBI, The learning environment of MBI, and The assessment of MBI.

Eli Tucker-Raymond Maria C. Olivares

Expanding Science Teacher Learning through Critical Relationality

Central to equity-focused reforms in science and engineering education is the need to expand what is valued in disciplinary learning, desettling taken-for-granted norms about what counts as valuable ways of knowing, reasoning, and communicating. Creating more expansive spaces for learning science and engineering supports learners to see more of themselves in these disciplines, to bridge their families' and communities' cultural practices and experiences to their disciplinary work, and to disrupt powered racialized and gendered hierarchies in schools. This related paper set examines the contexts of teachers' learning to develop more expansive learning environments in science and engineering. Looking across pre-service and in-service teacher learning communities, this symposium will consider different designs for fostering teachers' learning; explore different lenses for examining how teachers support expansiveness in science and engineering; and investigate the tensions teachers experience as they challenge culturally dominant frames of teaching and learning science. These papers aim to contribute to ongoing conversations about broader sociopolitical contexts of expanding what is valued in science and engineering, taking a teacher-focused lens to understanding how to achieve more equitable spaces for learning these disciplines.

Emily C. Turner Robert D. Bennett

Impacts of Professional Science Experience on Induction Science Teachers' NOS understandings, Pedagogy, and Science Identities

Teaching about nature of science (NOS) is a widely accepted component of building scientific literacy as an outcome of science education. This study was designed to explore connections between understandings of NOS, science identities, and instructional goals and practices among secondary science teachers with varying levels of professional science experience. Induction science teachers with diverse science backgrounds and enrolled in a master's level NOS course were recruited for this study to investigate how their previous experiences in science impacted their NOS understandings, their science identities and science teacher identities, and their pedagogy as it relates to teaching NOS. Data sources include VNOS, coursework, discussions, lesson plans, and interviews. Results indicate that professional science experience was not required for science teachers to maintain a science identity. However, teachers with professional experience were less responsive to NOS instruction and struggled to develop explicit and reflective learning opportunities for their students. Results indicate that professional experience was not connected to NOS understandings.

Ekaete Udoh Michele Williams

"Radical Openness and Possibility": Black Women's Resistance Strategies to the Oppressive Culture of STEM

Undergraduate Black women in STEM will encounter some type of microaggression that they must overcome in order to advance. Black women shared their experiences with gendered-racial microaggression in the STEM environment and the form(s) of resistance they used to navigate these unwelcoming spaces in 28 focus groups conducted at a predominantly white institution. The Black women stated that they faced a variety of gendered-racial microaggressions from classmates, teachers, and staff in STEM workplaces and that they navigated STEM culture through a variety of ways of resistance, some beneficial and others benign. It is critical for institutions of higher education to examine racism, particularly covert racism, that contributes to hostile STEM environments where Black women are microaggressed and forced to resist.

Dewi Ungu Mihye Won

Students' Construction of Learning Activities to Understand the Formation of Snowflakes with Three Different Modes

This paper-set arises from recent research with 130 undergraduate students enrolled in Chemistry using immersive virtual reality (IVR). Students worked in pairs to investigate molecular structure, polarity, and intermolecular forces for simple and complex molecules. Investigations of students' interactions are based on video recordings, conversation transcripts, conceptual diagrams, and machine-generated location logs. Paper #1 presents an analytical framework of thirdspace to explain the dynamic transactions that take place in the students' physical environment, the designed virtual environment, and the experienced learning in IVR. Paper #2 focuses on how learning the same chemistry concept in different modes - physical magnetic model, computer simulation, and IVR application - afford different spatial explorations resulting in different conceptual discussions and social interactions. Paper #3 examines how students construct different patterns of spatial, conceptual, and social interactions during their learning experiences in IVR depending on the presence of the researcher's scaffolding. Paper #4 investigates changes in students' interactions within IVR as they experience three separate VR programs over a semester—water molecules and ice crystal formation, stereochemistry and taste receptor, and neurotransmitter and enzyme reaction. This related-paper set offers an insightful and productive way to investigate students' experiences, interactions, and chemistry learning within IVR.

Bhaskar Upadhyay Kamal P Koirala

Community driven and relational STEM Teacher Leadership: Perceptions of Indigenous Female Teachers

This is a case study of a science professional development workshop in Nepal with elementary teacher participants from public schools. Most of these schools served the majority of Indigenous students in elementary, middle, and high school. The workshop focused on educating and building science teacher leaders for culturally relevant teaching for antiracist pedagogy by valuing and integrating Indigenous leadership practices and the local knowledge. The teachers participated in a 2-day workshop co-organized by the local district education office and the local high school. Data collected and analyzed showed (a) struggles to prioritize Indigenous science knowledge over Western science content, (b) teachers seeking affirmation to be science teacher leaders modeled on Indigenous leadership values, and (c) greater willingness for Indigenous leadership among female and Indigenous teachers.

Cansu Basak Uygun Ozgul Yilmaz-Tuzun

Investigating Relationship(s) Between Epistemological Beliefs, Argument Quality and Informal Reasoning in the Context of SSI

This study focused on investigating the relationship between middle school students' epistemological beliefs, argument quality and informal reasoning across three different SSI namely space explorations (SPE), genetically modified organisms (GMO) and nuclear power plants (NPP). Correlational design was adopted. Total of 101 students (39 female, 62 male) were constituted the participants. Written arguments were coded based on the Lakatos' Scientific Research Programmes and SEE-SEP Model. It was found that students displayed the most sophisticated epistemological beliefs on justification. It was found that the participants had the highest total score on SPE and mostly reported that they are sure of their decisions, however they generated less than one PH and NH for each SSI. Participants mostly used value regardless of the SSI topic; the arguments were mostly from the subject area of science. Correlation analysis revealed that source/certainty was positively correlated with PH and NH on SPE; NH on NPP topic. Development was positively correlated with NH on NPP. Justification was positively correlated with PH and NH; and the total score on SPE. Total codes used while generating counter-arguments on NPP was positively correlated with both source/certainty and development. Justification was positively correlated with total codes used while generating counter-arguments on SPE.

Ana Valdmann Miia Rannikmae

Defining Teacher Ownership: A Science Education Case Study to Dertarmine Categories of Teacher Ownership

This study seeks to put forward a justified definition for the concept of Teacher Ownership, and establishes levels of science teacher ownership, based on a hierarchy of categories, using phenomenographic analysis. Such ownership is based on a meaningful science teacher internalisation of

a motivational context- based teacher approach, established via a prior CPD programme. In so doing, the study distinguishes between teachers' self-efficacy levels attained at the end of the CPD and teacher ownership indicating the capability of propagating the desired teaching to students and other teachers. The phenomenographic analysis, based on semi-structured interviews, is carried out with 10 science teachers, 3 academic years after the administered CPD program. From an analysis of perceptions, 3 distinct categories of sustainable science teacher ownership, based on 5 distinct teaching dimensions, reflect variations in the orientation of teacher ownership. The main conclusions are that sustainable teacher ownership differs from terms such as a sense of ownership, towards ownership and self– efficacy and that, in this study, teacher ownership can be described as being exhibited by the science teachers in paradigmatic, experiential and emotional ownership categories.

Victoria J. VanUitert Michael J. Kennedy

The Effect of Teacher Participation in Multimedia Professional Development on Science Achievement Among Middle-School Students

Science consists of many complex, specialized terms that are often not explicitly taught in the science classroom which may leave students, especially those with disabilities, developing incomplete or inaccurate understandings of what the words mean. To support middle-school science teachers to provide evidence-based vocabulary instruction in inclusive classrooms, researchers created a multimedia professional development (MPD). Data collected from a randomized-control study was analyzed to determine the influence on science achievement of students with and without disabilities (N = 983) by having a teacher who participated in the MPD. Conducting multilevel modeling analyses, student science achievement growth was evaluated based on their teacher's access to the MPD. Findings indicate that having a teacher that participated in the MPD had a postiive impact on student science content knowledge. For instance, students with disabilities that had a teacher that participated in the MPD (N = 6) significantly outperformed on the science posttest measure than students without disabilities who teacher did not (N = 7). This session will provide detailed information about the intervention, the data collection, and the findings. Implications of the findings for supporting middle-school science teachers on how to provide evidence-based vocabulary instruction to students with and without disabilities will be discussed.

Richard Velasco Yujiro Fujiwara

Employing the Stereotype Content Model's Dimensions of Warmth and Competence to Identify and Categorize the Portrayal of Scientists in Meme-Based GIFs

Memes within graphical interchange formats (GIFs) are developed and shared for a wide global audience via the Internet. One subject of meme-based GIFs are scientists. Media-based scholarship has evidenced concern of the social perceptions of science and how scientists are portrayed. This study explored stereotypes using Warmth and Competence dimensions from Fiske's Stereotype Content Model to code and categorize 287 meme-based GIFs of scientists sourced the online Giphy repository.

Analyses found the stereotype most represented was the high-competence and low-warmth categories followed by the high-competence and low-warmth stereotype categories. This study suggests that although there have been improvements in the portrayals of scientists in media, however, GIFs may preserve and perpetuate the trope of the competent, yet cold, scientist.

Claudia Vergara Arlette Bassaber

Capturing Collective Pedagogical Content Knowledge (cPCK) of Evolution for understand how biology teachers develop their personal PCKevo

This article proposes a new model of pedagogical content knowledge (PCK), taking concepts from the Refined Consensus Model (RCM) and the model of Magnusson, Krajcik, & Borko (1999) and applying it to the content of evolution by natural selection. Based on the collaborative work and the experience of a long-term (9 years) professional development work, a collective PCK proposal was generated, which serves as a reference to evaluate the PCK development of 7 female biology teachers. Through the application of Content Representations (CoRe) pre and post for each teacher, their PCK was compared in terms of: i) changes in total area, ii) changes in diagram shape, and iii) changes in codes identity. The results showed that the 7 biology teachers increase in total area of their pPCKevo, due to the increase the number of cPCKevo concepts in their post CoRes, after conducting their lessons. The shape of pPCKevo increase mostly due to the pPCK aspects related with students understanding and instructional strategies. The new mix-model is efficient in portrait the development of pPCK of teachers and it is dynamics because a new cPCKevo can be built if new process of creation, including new teachers' knowledge, are generated.

Elizabeth Vergis

Effect of Demographic Factors on the Understanding of Concepts of Evidence: A Mixed Methods Study

The gap between recent chemical knowledge accumulated by research, and the knowledge taught in schools is widening. Scientists communicate their findings through scientific publications in peer-reviewed journals referred to as primary literature. Research suggests that first year students are hesitant to read primary literature. It has been found that adaptation of primary literature – referred to as adapted primary literature (APL) – nurtures students' ability to think scientifically. APL is a genre which still retains the canonical form and authentic results of the primary literature, but which, in this study, is made readable for first year university undergraduate students. In my PhD study, I used APL to test the understanding of Concepts of Evidence (CoEs) held by first year undergraduate students. CoEs are ideas that dictate how evidence can be collected, verified, analysed and interpreted. Numerous studies have examined whether test scores and demographic factors are correlated, and whether they have any bearing on academic performance. However, the understanding of CoEs – thought of as the non-academic equivalent of test scores - has never been measured using APL. In this study, I hope to investigate whether demographic factors such as, age, gender, socioeconomic status, ethnicity etc. have any effect on the understanding of CoEs.

Tina Vo Margarita Huerta

Exploring connections between anxiety and science understanding around Covid-19

COVID-19 has undoubtedly changed the current landscape of education, exposing a deep need for science literacy (CDC, 2021) in line with calls made by reform documents across the last few decades (NRC, 2013; NRC 1995). Pre-service teachers are having a unique experience within this ever-growing complex tapestry, as practicums were pushed online, and the training they received is delivered virtually. Additionally, evidence indicates that this global pandemic has disproportionately impacted vulnerable populations (Sharma et al., 2020) while causing increased anxiety and stress as individuals search for answers while deluged in misinformation (Xiao et al., 2020). The NGSS (2013) Science and Engineering Practices outline multiple ways science literacy individuals could engage with finding empirically grounded information (e.g., using models, analyzing and interpreting data); however, practice 8 "Obtaining, evaluating, and communicating information" seems particularly relevant. This work presents evidence that pre-service teachers defer science decision-making to authority around COIVD-19 and that lowering situational anxiety might be connected to adding coping mechanisms.

Sarah Voss Jerrid W. Kruse

Relationships Among Preservice Science Teachers' Discipline-, Domain- and Topic-Specific PCK - An Exploratory Study

The majority of science education research into pedagogical content knowledge (PCK) has focused on describing and developing PCK for different science topics. However, teachers also seem to have PCK relating to broader levels of science knowledge (Carlson & Daehler, 2019; Veal & MaKinster, 1999). Because there has been limited investigation into different levels, or grain sizes, of PCK, further investigation is warranted to describe discipline, domain, and topic-specific PCK and investigate the relationships among them. An increased understanding of the different levels of PCK may afford more thorough investigations into the preparation of science teachers, particularly in the context of teacher preparation programs. Two preservice teachers participated in the study. Data were collected through the use of Content Representation (CoRe) documents (Loughran et al., 2004) and semi-structured interviews. Qualitative analysis revealed preservice teachers were consistent in their approach to teaching across the three levels of PCK. However, they struggled to think beyond individual lessons or units and demonstrated only general ideas about how to organize topics within broader frameworks. Thus, illustrating the need to support preservice teachers in identifying relationships between different topics or domains and reflect on how they might facilitate similar connections for students.

Katherine Wade-Jaimes Rachel D. Askew

Teaching Science for Social Justice Using an Identity Framework

The challenges of teaching science in urban areas have been well documented, including high teacher turnover and lack of agency. In order to address these challenges, as well as the underrepresentation of students of color in science fields, we argue for a need to prepare science teachers to teach in socially just ways. This paper presents a description of a professional development program focused on both theoretical and practical applications of science identity and explores how participation in the program impacted teachers' understanding of teaching science for social justice, their own identities as science teachers, and their students' identity. Using data collected during and after a week long professional development, including teacher artifacts, reflections, and interviews, we explore how teachers described their experiences and understanding of identity. Findings included the importance of theoretical applications and time to reflect within professional development, and a need for ongoing support for in-service teachers. This work has implications for both preparing and supporting science teachers to teach in socially just ways.

Katherine Wade-Jaimes Rachel D. Askew

Case Studies of Science Teachers' Experiences With a State Law Banning Critical Race Theory

Critical Race Theory (CRT) has recently been "banned" in k-12 education in several states through state legislation. This paper presents case studies of two science teachers in one such state as they prepare to teach under this ban. Through interviews, reflections, and group discussion, we explore how teachers made sense of this law in terms of teaching science and the impact of the law on their identities as science teachers. Using a combined framework of CRT and identity, we highlight how this law is perceived by teachers as a way to formalize colorblindness and perpetuate education as a property of whiteness by targeting urban school districts. An important finding is the way in which teachers' pre-existing identities as activists, advocates, and anti-racists educators were strengthened and blended with science teaching identities through consideration of this law. Ongoing work will continue to follow the teachers and their identity development as they teach science under this law.

Steffen Wagner Burkhard Priemer

Systematic Assessment of Future Primary School Teachers' Interests in Science

While much research has been done on children's interest in science, pre-service and in-service teachers' interests have remained underexposed. Therefore, we conducted an exploratory study to systematically investigate future primary school science teachers' (FPSTs') interest in science. From October 2018 to April 2020, we asked 504 German university students who are trainee primary school teachers to name their topics of interest in science and to formulate a question they would like to ask a scientist. We have classified the responses into categories and sub-categories, mainly structured after scientific disciplines and sub-disciplines. We have analyzed the (sub-)categories qualitatively as well as the frequency at which they were mentioned. The results show a broad spectrum of students' interests, dominated by topics related to biology. Moreover, when asked to name a topic or formulate a question they would like to ask a scientist, the students expressed different interests. Some interests in, e.g. the

nature of science, appear predominantly in the students' questions. The results provide a systematic overview upon which educators can build interest orientated courses and lecture design.

Noemi Waight Jennifer Tripp

"It's really important to me for kids to get interested in and become aware of the options that are available to them in the STEM": Culturally Responsive School Leadership

This study examined the role of school leaders and their impact on STEM domains at the precollege level. This study examined the role of a school leader at a STEM-inclusive high school in an urban community. More specifically, we examined the role of the school leader, the nature of STEM-informed decision making and the culture of school science cultivated by the school leader. The theoretical framework, culturally responsive school leadership informed the study. The following questions guided the study: (a) What roles do school leaders serve, and more specifically, what is the nature of the decision making practices at an ISHS that serve minoritized students? (b) In what ways do these practices reflect culturally responsive school leadership (CRSL)? The findings revealed three main themes espoused by the school principal. These themes focused on the school culture, the role of teaching and learning, and being an advocate for STEM, and defining what it means for students to be successful in STEM. The findings have implications for understanding how school leaders translate policy for school science and STEM and how these practices become enacted at the classroom level. Even more important, the study also informs our understanding of the function of ISHSs and the ways in which these kinds of schools promote STEM practices for ethnic, racial and linguistically diverse urban high school youth.

Noemi Waight Shakhnoza Kayumova

Re-Constructing the "Black" Box and Making it Transparent for the Future of Science and Technology in Science Education: Towards Equitable, Social Justice Criticality

In the wake of the COVID-19 pandemic, which has resulted in the rapid emergence of vaccines, the dual benefits of both science and technology have been lauded while dominant, deficit-based narratives of vaccine hesitancy and mistrust in science and medicine by the general public, particularly minoritized populations, run rampant. In this position paper, we argue for a counternarrative, where instead of erroneously positioning communities of color as the problem, the problem is reframed to consider what the scientific, technological, and science education communities need to do to become more trustworthy and transgress the persistent shortcomings related to racism and injustice. Specifically, in this position paper we (a) discuss the interactions of science, technology, and society from the perspective of the nature of technology, (b) engage an understanding of how bias, access, and racism operate in and at the intersection of science, technology, and technological systems, (c) discuss implications of these ideas in science education, and finally, (d) pose recommendations to counter alienation and racism with an emphasis on a sixth dimension, equitable, social justice criticality, for science-technology education. In conclusion, we make recommendations by centering a more equitable, social justice criticality of science and technology.

Claudia Walker Heidi B. Carlone

Fifth-Grade Engineering and Language, Culture, and Identity: Lessons Learned by Teacher and Researcher

This related paper set is a collaboration of scholars and practitioners from different stages in their careers and explores various methodological, theoretical and pedagogical approaches to move towards justice and equity in science and engineering education. The five papers in this proposal focus on creating opportunities for traditionally marginalized voices to contribute their values and practices towards the creation of knowledge and solutions for all. The set addresses the question of how scholars, practitioners, and community members can work together in bringing the wealth of experiences and practices of students and their lived realities into science and engineering. In alignment with the NARST presidential theme, the presented scholarship addresses "issues of racial inequities and social injustices related to science" and engineering. The ideas presented in these papers call on us to cherish and invite the richness of cultural, cognitive, and linguistic resources that Black and Latinx students bring for engagement and learning in science and engineering while staying true to their communities.

Jamie Wallace Jenny D. Ingber

Dioramas as a Place for Play and Early Science Learning: Exploring Teachers' Perspectives and Experiences

In this qualitative study, we explore teachers' perspectives and experiences with play and learning at dioramas as few studies on this topic exist. In a time when play is disappearing from classrooms (Nicolopoulou, 2010), scholars advocate for a return to play-based learning (Miller & Almon, 2009). Using grounded theory (Charmaz, 2006), we inquired: 1) How do teachers describe the ways in which children play and learn with dioramas during their classes?, 2) What do teachers perceive as the affordances and opportunities that dioramas provide for children's play and learning?, and 3) What strategies and pedagogical decisions do teachers make to promote play and learning at diorama? We interviewed ten early childhood educators who teach at a large, urban museum. Nearly 30 unique examples of play and learning with dioramas were provided, nine referenced by multiple teachers. Findings suggest that play and learning at or inspired by dioramas looks different across classes and contexts, but is perceived as vital in sparking imagination and creativity for young children when integrated into experiences and affords unique opportunities. This study highlights how dioramas can be integral in play-based science learning—making museums that are not traditionally designed for children into places for play.

Emily M. Walter Micah J. Johnson

Going beyond the Content: Impact of a Values Affirmation Writing Exercise on Student Outcomes in an Undergraduate Majors' Biology Course
Achievement gaps between underrepresented minority (URM) students and their peers in STEM classrooms are common in institutions of higher education. In this study, we posit that student success in STEM results in part from supporting students' social and emotional well-being. We propose doing this via writing tasks called "values affirmations". VA tasks support all students, but especially those who are most likely to experience a negative classroom climate. In this study, we explored the impact of doing a VA task on course grades and students' attitudes about biology in a science majors' introductory biology course. We surveyed 162 students in summer 2020, fall 2020, and spring 2021 at a majority-minority institution. Although we did not find course grades were significantly higher for students who experienced the VA (p=0.06), URM students in the VA group had on average ¼ a letter grade higher than URM students in the control group. We also found significantly higher attitudes about learning biology in the experimental group, including attitudes about real-world applications, enjoyment, and effort. These attitudes were significantly correlated with student grades in the course, and other studies have shown these attitudes to carry forward to positive outcomes in future courses.

Jianlan Wang Yuanhua Wang

Investigating learning assistants' use of questioning in the online setting of an inquiry-oriented physics course

Learning Assistants (LA) play an important role in inquiry-oriented physics instruction in large classrooms. They increase teacher-student ratio and provide timely support to student exploration. Questioning is believed to be an advantageous strategy for LAs to scaffold student learning and maintain students' agency in knowledge construction. Unfortunately, there are few instruments for the measurement and preparation of LAs' competence of questioning. It remains obscure how LAs use questioning in their interaction with students and how their questioning contributes to students' conceptual understanding. In this study, we developed a coding scheme to analyze LAs' questions from class videos. We also designed a written instrument with questions describing various situations that LAs would encounter while teaching classical mechanics. We used these instruments to measure performed and narrated Pedagogical Content Knowledge regarding Questioning (PCK-Q) of three LAs with various experiences of being an LA in an inquiry-oriented physics course taught online during the COVID pandemic. We examined the validity and reliability of both instruments, delineated the LAs' PCK-Q, gauged LA-student interaction in online setting, and suggested how the LAs intervened with students' conceptual understanding. We also discussed the use of these instruments for large-scale quantitative analyses on LAs' PCK-Q.

Jianlan Wang Yuanhua Wang

Examining elementary pre-service teachers' competence of questioning in leveraging students' conceptual understanding

Questioning is a critical pedagogy for science teachers to support students' exploration and knowledge construction in inquiry-oriented science teaching. Scholars suggest a questioning chain in terms of I-R-F-

R-F but does not specify how follow-up questions (F) should be connected to each other to step-by-step lead students to in-depth conceptual understanding. Besides, open-ended questions are overemphasized with limited attention to teacher guidance embedded in questions, which may mislead Pre-Service Teachers (PST) towards hands-off science teaching where students' conceptual learning merely counts on articulating their own thoughts. In addition, existing methods for question analysis are mainly qualitative, which is unwieldy for large-scale quantitative analysis with many PSTs in science teacher education. In this study, we will present a quantitative instrument and illustrate the method of deriving elementary PSTs' pedagogical content knowledge of questioning. We will discuss the validity and reliability of both free-response and multiple-choice versions of this instrument and its use in science teacher preparation.

Lu Wang

The impacts of content area on novice teacher noticing-a preliminary analysis

This project investigated the impacts of teachers' content areas on what and how they notice. Participants are a group of middle-grades science and math teachers. Their noticing was elicited through observations of middle-grades science and math videos. Employing a qualitative research design, the preliminary analysis of data suggests the connections between what and how teachers notice and their content areas. Specifically, although teachers identified same moments when they watch a video aligns with their content area and a video different from their content area, they paid attention to different events within the same moments. Second, novice teachers tend to be more interpretive when watching the video aligns with their content area. Finally, the ways novice teachers made connections to their own teaching practices seem not to be related to their content areas.

Abdirizak M. Warfa Marin Melloy

Analysis of graduate teaching assistant discourse behaviors and the effects of a professional development intervention

Teacher Discourse Moves (TDMs) can enhance or limit the occurrences of dialogic talk in active learning classrooms. In this study, we examined the TDMs used by Teaching Assistants (TA) in undergraduate laboratory classrooms and the effects a professional development (PD) intervention had on them. To do this, we studied a group of TAs teaching class sessions (N = 102) in an undergraduate biology laboratory. Half of the TAs received PD training as an intervention while the rest did not. Our results show that intervention TAs used more dialogic talk and less traditional lecture approaches compared to control TAs. We also found the intervention TAs used more dialogic approaches subsequent to the completion of treatment. These findings help us understand the nature of TA discourse and what factors in a PD might shift their stance from using simply authoritative talk to more dialogic and student-centered one.

Jessica Watkins Natalie A De Lucca

Toward More Expansive Science Learning for Pre-Service Teachers

Central to equity-focused reforms in science and engineering education is the need to expand what is valued in disciplinary learning, desettling taken-for-granted norms about what counts as valuable ways of knowing, reasoning, and communicating. Creating more expansive spaces for learning science and engineering supports learners to see more of themselves in these disciplines, to bridge their families' and communities' cultural practices and experiences to their disciplinary work, and to disrupt powered racialized and gendered hierarchies in schools. This related paper set examines the contexts of teachers' learning to develop more expansive learning environments in science and engineering. Looking across pre-service and in-service teacher learning communities, this symposium will consider different designs for fostering teachers' learning; explore different lenses for examining how teachers support expansiveness in science and engineering; and investigate the tensions teachers experience as they challenge culturally dominant frames of teaching and learning science. These papers aim to contribute to ongoing conversations about broader sociopolitical contexts of expanding what is valued in science and engineering, taking a teacher-focused lens to understanding how to achieve more equitable spaces for learning these disciplines.

Vashunda Williams Warren

Lived Experiences of K-12 Teachers Who Attended Professional Development Hosted By Informal Education Institutions

The purpose of the current study was to illuminate the lived experiences of K-12 teachers who attended teacher professional development sessions hosted by informal education institutions for consecutive or multiple years. The current study was a hermeneutic phenomenological study. The data collection and analysis process was conducted in three phases. In Phase 1, social media posts were used to recruit 29 potential participants who attended professional development hosted by informal education institutions. In Phase 2, 21 identified participants were interviewed using interview guided open-ended questions. Data for 12 participants, who met inclusion criteria, was analyzed using revealing three overarching themes: connectivity, engagement, and relevance. In Phase 3, identified informal education institutions were surveyed, highlighting demographics, structure of, and support for education. Illuminations from the current study revealed that when K-12 teachers attended teacher professional development hosted by informal education institutions experiential and transformative learning occurred. Scholarly writings about teacher professional development and informal education institutions in relations to active learning, expert input, social interactions, and specific content confirmed the current's study findings that access to specialists, collaboration, content knowledge, and hands-on activities, were significant to the phenomenon (Desimone, 2003; Faulk & Dierking, 2018; Jones, 2011).

Shari Watkins

Brian McGowan

Exploring Racism in the Undergraduate and Graduate School Choices of Scientists and Engineers: Counterspaces for Black men in S&E

This qualitative study explores the role of racism in the undergraduate and graduate school choices of Black men who pursue science and engineering (S&E) as a field of study. Also examined are the ways the men seek out and perceive counterspaces which support their decisions to pursue S&E. Counterspaces, spaces or sites that counter racism, is the conceptual framework. In the CRT tradition, counterstorytelling, a critical race methodology (CRM) is used as the methodological framework to capture the perspectives of 16 Black men PhD scientists and engineers and the ways racism influenced their postsecondary school choices. Three themes focused on counterspaces for Black men in S&E are presented. This paper contributes to the literature focused on S&E persistence by investigating the connections between racism, counterspaces and undergraduate and graduate choices of Black men pursuing S&E. Through our intentional focus on lifting up the experiences of this population, our research aligns with the NARST 2022 conference theme focused on inclusion as way to build community. Implications exist for higher educators, science educators and S&E faculty interested in supporting the persistence of Black men pursuing and completing S&E postsecondary degrees.

Ellen Watson

What is Physics? Considering Teachers' Epistemic Beliefs about Physics Knowledge

Teachers are not often provided the opportunity to explore their beliefs about, and the philosophy behind, their subject. Since teachers' epistemic beliefs inform their practice, it is important that educational researchers include teachers in these conversations. This study invited teachers across a Western Canadian province to explore their epistemic beliefs about physics knowledge. Using semi-structured interviews, teachers were asked about their epistemic beliefs in each of four areas of physics knowledge described within a literature derived framework: the (1) structure, (2) source, (3) certainty, and (4) content of physics knowledge. Thematic analysis was used to develop themes and teachers were represented along four continua of epistemic beliefs about physics knowledge, providing a new way of visualizing teachers' epistemic beliefs. Findings from this study question the previously claimed assumption that teachers' epistemic beliefs aligned with those of expert scientists. Findings also suggest further measures be taken to engage practicing teachers with their epistemic beliefs about physics knowledge. To facilitate these conversations with practicing teachers, this session presents an applied strategy to encourage teachers, and pre-service teachers, to explore their epistemic beliefs about physics knowledge.

Joseph V Watts Corey A. Payne

The Varied Student Experience with Transitioning to Mandatory Online Chem Lab

The radical global shift to online teaching that resulted from the COVID-19 pandemic forced many science educators into the predicament of translating courses, including teaching laboratories, that were based upon face-to-face or practical goals and conventions into ones that could be delivered online. We

used this phenomenon at the scale of a research-intensive, land-grant public institution to understand the various ways that the switch was experienced by a large cohort of undergraduate students taking General Chemistry Laboratory. Results are organized according to strengths, weaknesses, positive and negative implications across 21 topics with dimensions or critical aspects. Consistent with other reports, participants perceived Availability of the Teaching Assistant for Help (accessibility, accomodation) as the predominant positive implication, with Hands On Experience (procedures, content knowledge) Preparation of Future Laboratory Work (hands-on, lab skills), and Specific Implications (content knowledge, grades) as highly reported negative implications. Notably, Time Management for Assignments (adaptable and flexible, independence and self-reliance) was the foremost weakness for URM students. The more comprehensive understanding provided by this study can inform the design and development of more inclusive forms of online chemistry laboratories. Our results will be of interest to all STEM faculty, especially those responsible for laboratory courses.

Kim-Alessandro Weber Rüdiger Scholz

Hands-On Learning About Inclusion in an Undergraduate Physics Lab

Inclusion has been one of the central and also intensively discussed topics in education in recent years. The background to the project has been a serious change in teacher training, which requires inclusion to be compulsory in all subjects. A concrete implementation of this requirement in the subject of physics within a laboratory course is reported. Physical disabilities are experienced and the role of an assistant is tested during an undergraduate laboratory course. The results prove the acceptance of this implementation and show that not only student teachers but also physics students benefit equally from the new lab course experiments.

Andrea E Weinberg Amanda Cicchino

Critical pedagogy of place to enhance ecological engagement activities: Expanding "place" beyond the biophysical

Academics fill a unique dual position as both stakeholders and facilitators of engagement activities in K-12 settings (Bogue, 2005; Appel et al., 2020), although students engaging in these programs as participants are tthe primary stakeholders. Without direct consideration of this primary group, as well as the other K-12 stakeholders such as teachers, academics leading engagement programs may direct the program around their own goals (Sadler et al., 2018), which means the potential of the efforts may not be fully realized for any stakeholders, including academics initiating the engagement experiences. In this paper, we present an approach to critical engagement in K-12 settings that draws from frames of reference familiar to ecological and biological scientists, and expands on prevalent notions of engagement to broader communities, who may include future natural scientists. Just as our colleagues call on science teachers to adopt critical pedagogies to empower learners, we argue that ecologists involved in engagement activities must adopt a critical lens that starts and ends with social justice and inclusivity as catalysts.

Laura A Weingartner Emily J Noonan

Education Research Experiences for Pre-Health Students Enhance Clinical Skills and Develop Awareness of LGBTQ+ Microaggressions

Research experience is valued by health professions schools, but often pre-health student research is lab-based and biomedically focused without considering health equity issues. We show that disparities research in health professions education can provide alternative, relevant research experiences to prehealth students while teaching inclusivity in health care settings. We describe a program in which prehealth students studied how microaggressions influence healthcare delivery. Students learned quantitative and qualitative research skills to analyze videos of standardized patients with gender and sexual minority identities interacting with medical students during a health history. Pre-health students coded the presence/absence of clinical behaviors related to LGBTQ+ microaggressions and designed independent, education-based research projects to pursue with the assessment dataset. Results from some of these independent projects showed that 1) hetero/cis-normative language and assumptions were common; 2) questions about social determinants of health increased after providers completed health equity training; 3) healthcare referrals based only on identity decreased after training. The research experience enhanced clinical skills development of pre-health students as measured by a pre/post-project assessments and standardized patient encounters. Post-project encounters contained more thorough, patient-centered histories and more complex communication skills. Pre-health students also reported gains in interpersonal communication and understanding of health equity.

Jill Wertheim Miray Tekkumru Kisa

Teacher Agency in a Responsive Co-Design Process of 3D Performance Assessments

Numerous states and districts are seeking classroom-based performance assessments that support their goals for equitable 3D science instruction, but few quality assessments exist. We introduce a responsive co-design process that positions teachers and researchers as experts in different domains of the assessment design and places responsibilities on each that leverages their distinct expertise. Researchers do much of the time-consuming development while teachers focus their efforts around five critical points. Limiting teachers' involvement is only effective if they feel a sense of agency in shaping the design during those five co-design meetings. We examine the experience of seven 8th grade science teachers from a large urban district who participated in ten co-design meetings over six months. Triangulation across thematic analysis of videos and exit tickets from co-design meetings, and teacher interviews, revealed specific ways teachers perceived their influence as individuals and as a group and the elements of the responsive co-design process that enabled high levels of agency. This work builds on the current knowledge-base by describing a process for using specialized roles for teachers and researchers to build capacity for the design of 3D performance assessments.

Emma Wester Lisa L.

Lisa L. Walsh

Student emotional engagement through the emergency transition to online learning due to COVID-19

Numerous quantitative studies in science education found that student engagement declined after the onset of the COVID-19 pandemic, but analyses to identify the educational factors that drove engagement down are lacking. This study used qualitative analysis to examine how the emergency shift from face-to-face classes to online classes during (March 2020) and after (May 2020) the pandemic-induced emergency remote transition impacted student emotional engagement. Emotional engagement is a multidimensional construct composed of interest in an academic discipline, value in an academic course, and anxiety. We coded student responses using an emotional engagement framework and compared their responses between March and May, 2020. Our quantitative data showed a significant decline in positive attitudes toward science, while the student values toward their science courses shifted toward more negative perceptions. Students' responses about their stress, their barriers to accessing online learning, and their opinions regarding the actual costs and benefits of online learning will help provide significant qualitative insight on how students emotionally experience an emergency disruption to their education and indicate teaching practices to prioritize in the future.

Jeanna R. Wieselmann Deepika Menon

Elementary Science and Engineering Teaching Self-Efficacy: Trends in the Literature and a Research Framework

Elementary teachers often have low self-efficacy for teaching science and engineering. While efforts to increase self-efficacy span across preservice teacher preparation courses and inservice professional development programs, details concerning the contexts in which science and engineering teaching self-efficacy develop are often limited, making it difficult to claim that gains in self-efficacy are long-lasting. In this presentation, we synthesize the existing self-efficacy research to: (1) explore the trends in science and engineering teaching self-efficacy research to: (1) explore the trends in science and engineering teaching self-efficacy research. (2) identify gaps in the literature, and (3) propose a research-based framework aimed to guide future research. The proposed framework allows for an indepth understanding of experiences critical to the development of self-efficacy within the preservice teacher preparation years, during the first years of teaching, and beyond the beginning years of teaching. Y hat target increases in teacher self-efficacy are discussed.

Karrie A. Wikman

Effects of Subsuming Standards-based Objectives within the SSI Framework on Content Acquisition and Global Citizenship

Although the literature is replete in conceptual and theoretical justifications for the implementation of the Socioscientific Issues (SSI) framework as an equitable approach for the cultivation of functional degrees of scientific literacy, actual implementation is relatively limited. Resistance results, in part, from the high-stakes nature of state and national assessments. Delivered curricula in assessed courses can consequentially be reductionist and lacking in the sociocultural aspects required for SSI reasoning and subsequent development of progressive forms of scientific literacy. Correspondingly, this quasi-

experimental mixed methods study aimed to move a large and diverse school district's science educators, administrators, and policymakers toward school environments conducive to the formation of character and values as global citizens. The following research questions guided the work: (1) What is the effect of subsuming standards-based objectives within the SSI instructional framework on science achievement? (2) How does an SSI curriculum with explicit key elements of functional scientific literacy (e.g., inclusive of moral reasoning for ethical conduct) affect the development of students' character and values as global citizens? Multilevel assessment data analyses quantitatively revealed that students experiencing the SSI intervention showed statistically significant gains in content acquisition as measured by both proximal and distal assessments. Qualitative analyses showed significantly large shifts in how students expressed all eight of the investigated socioscientific orientations associated with the domain of character and values as global citizens. The research also provides useful insights into the district's 2017 implementation of its SSI Unit Design Model that remains in place today.

Jennifer A. Wilhelm Merryn Cole

Seasons in the Sun: Unpacking Seasons Lesson Approaches as Teachers Model Earth-based and Spacebased Perspectives

The purpose of this study was to unpack the implementation of science units that incorporated seasons lessons. Participants were three 8th grade science teachers and their students at two schools (Maple N=110 and Spruce N=30) in an urban area of the desert southwest of the United States. Seasons lessons were videotaped and analyzed for the ways teachers modeled and used Earth-based and Space-based approaches to facilitate the spatial development for seasons understanding. Class coding involved four spatial domains of periodic patterns (PP), cardinal directions (CD), geometric spatial visualization (GSV), and spatial projection (SP). Other coding included Model to Confirm (MtC) and Model to Learn (MtL). Students were given a pre/post Geometric Spatial Assessment (GSA) as well as a mental rotation test to assess development. All teachers' enactments emphasized GSV and SP the most, resulting in one Maple teacher's students significantly improving on GSA SP items and on the Spruce teacher's boys significantly improving on the overall GSA. Other significant improvement occurred for a Maple teacher's girls showing increased PP understanding. Maple's enactments permitted more opportunities for students to MtL than Spruce. Spruce tended to model three phenomena (lunar phases, eclipses, seasons) within one representation which could lead to student confusion.

Jennifer A. Wilhelm Molly Fisher

What Does an Undergraduate Research Experience Look Like in STEM Education?

This mixed methods study investigated an education experience where preservice teachers conducted research while participating in a STEM education Research Experiences for Undergraduates program. We examined: To what degree can undergraduate research Fellows be successful with STEM education research when the research period is limited to one academic year? and What types of STEM education research projects are conducive for such a limited time setting? Survey, interviews, and self-reports conducted with the research Fellows were triangulated with their final project artifacts. Findings showed

Fellows achieved positive growth in their STEM research skills and began to identify as teacher researchers. Of the eight projects in the last two years, three have already been published in journals, three are under review with journals, and two are being finalized for submission. This research is the first to examine the effectiveness of an academic year interdisciplinary STEM Education REU program. REU programs typically are offered two months (8 weeks) between Spring and Fall semesters and within only one STEM content discipline located in schools of science and engineering, as opposed to education.

Nicola Wilkin Jaimie Lauren Miller-Friedmann

Ways of Identifying as Other: a longitudinal case study of women of colour in physics

Social inequalities in the field of physics has long been a global problem, and one that a wide variety of interventions and programmes have tried to solve. The endemic bias and discrimination in physics that deters or outright prevents women and people of colour from participating, continuing, and finding success in the field is not easily displaced. For those who identify as being members of more than one under-represented category, their experiences can be vastly different to those of either women or men of colour. This is a longitudinal mixed-methods study that investigated how women of colour in physics identify and envision the problems of bias and discrimination in the field. The three case studies delineate their bias experiences as either related to their gender, race/ethnicity, or their intersectional identity. Their vastly different experiences are likely due to the fact that physics does not provide a ready-made acceptable subjectivity for these women, and they struggle to create one for themselves. They do this against the wishes of their communities and, from their viewpoint, the physics environment. Further exploration into intersectional identities in physics is needed in order to create these subjectivites and create more inclusive physics environments.

Selene Y. Willis Dana L. Zeidler

Connecting Justice-Centered pedagogy to Students' Critical Science Agency in an Elementary and Middle School Science Classroom

The purpose of this proposal is to describe the results of a qualitative case study of two in-service elementary and middle school science teachers' classrooms and their motivations to use justice-centered pedagogy to facilitate the development of their student's critical science agency. This study was conducted at an independent K-12 school in the southeastern United States. The research question that guided data collection and analysis was: To what extent, if any, does justice-centered pedagogy develop students critical science agency? Semi-structured teacher interviews, student focus group discussions, audio-recorded lessons and researcher field notes throughout the course of a two monthlong science unit were analyzed. Data were coded inductively to determine themes and findings. There continues to be a gap between teacher's successful enactment of justice-centered pedagogical practices in the classroom, and the development of students' critical science agency. Insights from this study highlight a need for more in-service professional development for teachers to guide their ability to teach

science for social justice, a need to develop curricular resources for teachers and inclusion of explicit structures of social justice in science curriculum development.

Sascha Wittchen Claus Bolte

Assessment of chemistry teacher student's diagnostic competencies in the Simulated Chemistry Classroom (SiCC).

The pedagogical-psychological construct of diagnostic competence has a strong practical relevance, as adaptive instructional designs are not possible without knowledge of the performance and learning requirements of a specific learning group (Author 3 et al. 2016, p. 76; Retelsdorf & Möller 2016, p. 23). Accordingly, the ability to assess accurately should have a positive impact on students' learning growth (Möller et al. 2016, p. 16). A particularly objective and authentic assessment of diagnostic competencies can be achieved using the Simulated Classroom, a digital tool for simulating communication between students and teachers in the classroom (Fiedler et al. 2002; 2007; Südkamp 2010; Author 2 et al. 2011; 2021). As part of our research, we constructed a simulated classroom that, for the first time, captures all three dimensions of assessment (person-based judgements, task-based judgements, and task-specific judgments; Schrader 1989, p. 57). In our study, we address the question of the extent to which student teachers of chemistry are able to accurately assess simulated student's performances when having to use all three dimensions of assessment.

Mihye Won Dewi Ungu

An Analytical Framework for Spatial Analysis of Students' Interactions in Immersive Virtual Reality

This paper-set arises from recent research with 130 undergraduate students enrolled in Chemistry using immersive virtual reality (IVR). Students worked in pairs to investigate molecular structure, polarity, and intermolecular forces for simple and complex molecules. Investigations of students' interactions are based on video recordings, conversation transcripts, conceptual diagrams, and machine-generated location logs. Paper #1 presents an analytical framework of thirdspace to explain the dynamic transactions that take place in the students' physical environment, the designed virtual environment, and the experienced learning in IVR. Paper #2 focuses on how learning the same chemistry concept in different modes - physical magnetic model, computer simulation, and IVR application - afford different spatial explorations resulting in different patterns of spatial, conceptual, and social interactions during their learning experiences in IVR depending on the presence of the researcher's scaffolding. Paper #4 investigates changes in students' interactions within IVR as they experience three separate VR programs over a semester—water molecules and ice crystal formation, stereochemistry and taste receptor, and neurotransmitter and enzyme reaction. This related-paper set offers an insightful and productive way to investigate students' experiences, interactions, and chemistry learning within IVR.

Joseph T. Wong Natalie Au Yeung

Leveraging Learning Experience Design to Deploy Embedded Video Questions to Support Students' Online Learning Experience

This study is part of a series of in situ design-based research investigations within a large public R1 university in California, assessing undergraduate science instruction while distance learning. It has become increasingly important to identify sustainable learning alternatives to support online teaching and learning while integrating educational technologies informed by evidence-based practices of pedagogical learning experience design (LXD). Consequently, this design-based research efficacy study aimed to test the effectiveness of video embedded questions supporting or hindering students' learning experience. Results showed that learners who experienced the video embedded questions had significantly higher quiz grades, pageviews, and course participation as well as increased levels of online engagement, self-regulation, and critical thinking. Implications on how institutions may iteratively design and effectively foster successful science online teaching and learning with the deployment of innovative digital learning grounded in pedagogical learning experience design are discussed.

Sissy S. Wong Jie Zhang

Science Teachers' Views on the Integration of Science and Language for Emergent Bilinguals in Sixthgrade Classrooms

Integration of science and literacy during science instruction is important for student learning because it can facilitate reading, writing, discussion, and reasoned argument that enhance science learning. This qualitative study examined three sixth-grade teachers' views on the integration of science and literacy in classrooms with predominantly Emergent Bilinguals (EBs). The teachers implemented an inquiry-based and language-infused curriculum centered on a socioscientific Issue (SSI): Should the U.S. government increase funding for space exploration? Extended interviews with teacher participants were conducted after the the curriculum implementation to explore their views about science and literacy integration and working with EBs. Findings show that the teachers prioritized some views over others, held limited views about what integration entails, and possessed deficit views of EBs, which may have acted as constraints for science-language integration. Implications for teacher preparation program and professional development are discussed.

Steven Worker Martin H. Smith

Youth Participatory Action Research: Positioning Science Learning as and for Community Participation

Scholars have recognized a need to reframe science education as/for participation in the community. Scholars have argued for science learning focused on lived experiences that emphasizes socially oriented science learning reflecting the real-world needs of students. We implemented eight youth participatory action research (YPAR) cohorts over three years at five schools in Northern California with youth of color. The core YPAR approach is to empower youth, with the help of adult facilitation, to decide upon a research topic; design and implement the research; and then plan a project based on the research findings to improve their lives or community. With data generated from educator interviews and youth focus groups, analyzed with inductive thematic analysis, we explored what youth and educators reported about science engagement and learning. While we found YPAR projects touched on all aspects of scientific literacy (science content, scientific reasoning skills, attitudes/interest), youth did not join the YPAR program because it was "science", but instead because they were interested in their selected topic. Youth entered science through a personally meaningful topic (that was cross-disciplinary) that could affect community change. Engaging learners in relevant educational experiences situated in authentic community activities may improve motivation for deeper and sustained participation in science learning experiences.

Kraig A. Wray Amy R. Pallant

Investigating the Ways Students Leverage Lived Experience to Explain Phenomena

Choosing a relevant and appropriate anchoring phenomenon is one of the most challenging yet most essential tasks a teacher must accomplish to support student engagement in the practices of the NGSS (NGSS Lead States, 2013) and science more broadly. Ideally, the phenomenon should leverage student experience, be relevant to the student both culturally and to their community and allow for students to make sense of the science through their own ways of knowing. However, through preliminary data analysis, we saw that most students are maintaining a separation between their lived experiences within their communities and the ways they make sense when participating in school. Despite direct experience with wildfire and after completing an online module focusing on the risks and impacts of wildfire, even when directly asked, the students rarely drew on those experiences to help explain or justify their thinking regarding wildfire. A more thorough study will be conducted to better explain why students do not utilize their experiences and in what ways science teachers and teacher educators can best support students in making those connections.

Christopher G. Wright Rasheda Likely

Becoming a Teacher of Engineering as a Racialized Local Contentious Practice

This related paper set is a collaboration of scholars and practitioners from different stages in their careers and explores various methodological, theoretical and pedagogical approaches to move towards justice and equity in science and engineering education. The five papers in this proposal focus on creating opportunities for traditionally marginalized voices to contribute their values and practices towards the creation of knowledge and solutions for all. The set addresses the question of how scholars, practitioners, and community members can work together in bringing the wealth of experiences and practices of students and their lived realities into science and engineering. In alignment with the NARST presidential theme, the presented scholarship addresses "issues of racial inequities and social injustices related to science" and engineering. The ideas presented in these papers call on us to cherish and invite the richness of cultural, cognitive, and linguistic resources that Black and Latinx students bring for engagement and learning in science and engineering while staying true to their communities.

Christopher G. Wright Rasheda Likely

Centering Racialized Disciplinary Becoming in the Design of Teacher Professional Learning Communities

Central to equity-focused reforms in science and engineering education is the need to expand what is valued in disciplinary learning, desettling taken-for-granted norms about what counts as valuable ways of knowing, reasoning, and communicating. Creating more expansive spaces for learning science and engineering supports learners to see more of themselves in these disciplines, to bridge their families' and communities' cultural practices and experiences to their disciplinary work, and to disrupt powered racialized and gendered hierarchies in schools. This related paper set examines the contexts of teachers' learning to develop more expansive learning environments in science and engineering. Looking across pre-service and in-service teacher learning communities, this symposium will consider different designs for fostering teachers' learning; explore different lenses for examining how teachers support expansiveness in science and engineering; and investigate the tensions teachers experience as they challenge culturally dominant frames of teaching and learning science. These papers aim to contribute to ongoing conversations about broader sociopolitical contexts of expanding what is valued in science and engineering, taking a teacher-focused lens to understanding how to achieve more equitable spaces for learning these disciplines.

Diane Susan Wright Meena M. Balgopal

What keeps rural science teachers in rural schools?: Teacher professional resilience

High quality science teachers are important in preparing high school graduates to be scientifically literate citizens. Unfortunately, the U.S. is experiencing science teacher shortages particularly in rural schools. Using systems theory and capital framework, this case study identifies the professional, social, and emotional vulnerabilities and adaptations rural teachers navigate within their school and community environments. When teachers stay, move, or leave the classroom, their decisions are directly influenced by their thinking about the school environment, which in turn, is influenced by their personal, professional, and social contexts. Communities of practice provide different resources and capital, as well as a sense of belonging to a community. When rural science teachers are able to navigate the professional vulnerabilities in the school and the social vulnerabilities in the community by capitalizing the places, people, and community knowledge making up their communities of practice, they are able to build professional resilience and remain in the rural school system. It behooves teacher adaptations has implications on the resilience of the school system. It behooves teacher educators and school administrators to understand the contexts that influence teachers' intentions to remain or leave the school and take adaptive actions to manage school system resilience.

Gary W. Wright

Generating an operational framework of gender and sexual diversity (GSD)-inclusive STEM teaching: A systematic literature review

Students who identify as LGBTQ continue to report feelings of being unsafe at school due to their gender identity or sexual orientation. Access to an inclusive curriculum and supportive teachers may positively improve the school climate for LGBTQ students but these supports are often not included in STEM classrooms. One response is to ensure that STEM teachers are prepared to integrate GSD-inclusive teaching into their classrooms. This review systematically analyzed 81 empirical and non-empirical publications on GSD-inclusive teaching in K-12 and higher education STEM education contexts. The selected studies were qualitatively analyzed, and the results showed that: (1) GSD-inclusive STEM teaching is operationalized as six highly related components, (2) GSD-inclusive STEM teaching is mostly based in non-empirical work, and (3) GSD-inclusive STEM teaching is undergirded by multiple theoretical perspectives. This study operationalizes GSD-inclusive STEM teaching as a pragmatic integration of six essential components that are aligned with multiple contemporary critical learning theories. Additionally, there is a need for future research to utilize qualitative and quantitative methodologies to evaluate STEM teachers' capacity to integrate GSD-inclusive teaching into their future classrooms.

Jen-Yi Wu Ying-Shao Hsu

Pre-Service Secondary Science Teachers' Views on Teaching Socioscientific Issues

This research developed a short-term course for pre-service earth science teachers to cultivate their competence for teaching socioscientific issues (SSI). In this SSI professional development course, they participated in the following activities: working on an SSI online module in pairs, discussing teaching issues with each other, thinking about the issues with a science educator, and reflecting on practical issues shared by an in-service teacher. The effects of this course were explored by comparing the preand post-surveys with a questionnaire on teaching SSI. The results showed that the pre-service earth science teachers rated highly on the necessity of introducing SSI into the curriculum, but held a slight concern about students' competence. Significantly, their personal teaching efficacy beliefs with regard to dealing with SSI, and the scope of their SSI pedagogical content knowledge both improved. The features of the course are discussed in terms of its impacts on the professional development of pre-service teachers.

Peter Wulff Lukas Mientus

CoFee – Computer-based feedback design for written reflections in pre-service science teacher education

Learning from teaching experiences is a facilitator for professional development in science teacher education. In particular, reflection of teaching experiences and individual feedback positively impact the professional development. However, resource-based shortcomings in science teacher education hinder the efficient application of individual feedback on reflections. In this study we seek to advance utilization of artificial intelligence-based methods in science teacher education to facilitate individual feedback for reflections on teaching experiences. We employed a pretrained language model to analyze written reflections (N=273) of pre-service physics teachers in teaching internships. We found that artificial intelligence-based methods of machine learning and natural language processing can facilitate the

automated analysis of the structure of written reflections by pre-service physics teachers (RQ1). Furthermore, these methods could cluster segments in the written reflections according to topics that the pre-service physics teachers expressed in their written reflections (RQ2). The findings show that pretrained language models improve the automated analysis of structural elements and topics of the pre-service physics teachers' written reflections. For science teacher education these findings indicate that automated analysis and feedback for written reflection can be implemented in computer-aided tutoring systems that reach the performance level of human raters.

Song Xue Keith Topping

Knowledge, Practice and Product: Developing Preservice Science Teachers' Modelling Competence

Modelling competence can be defined as mastery with regard to insightful knowledge of models, the ability to judge model products concerning their purpose, and the ability to reflect on modelling practice. This paper provides a revised framework of modelling competence, including meta-modelling knowledge, modelling practice and modelling products. It goes on to describe an empirical study aimed at developing a modelling-based curriculum, assessment instruments and evaluation rubrics to promote and assess the development of preservice science teachers' modelling competence. The analysis indicated that the designed curriculum significantly improved preservice science teachers' modelling competence in each component. Furthermore, there was a strong positive correlation between practice and product, but no significant relationship with meta-modelling knowledge. These contributions helped address some contradictions in theories of modelling competency and empirical research of modelling practice and product in science education.

Fang-Ying Yang Yi-Wen Hung

Applying the eye tracking method to analyze university leaners' learning and reasoning behaviors in the Augmented Reality Environment

The emerging technology of Augmented Reality (AR) has the potential to become a powerful instructional tool supporting authentic inquiry and reasoning practices in classrooms. However, there is a lack of literature regarding how the AR technology may be used to assist the argument-based teaching and learning. In the study, an AR-based interactive instruction focusing on the argumentative reasoning on the topic of plate tectonics was designed and then tested. Thirty undergraduates aged from 20 to 23, with 21 female and 9 male students were recruited via the Internet to participate in the study. TheTobii Glasses 2.0 mobile eye tracking system was adopted to record students' eye movements during the whole learning process while students' argumentative reasoning was prompted with open-ended questions given in the AR instruction. The result showed that the AR-based interactive instruction as designed in the study has the potential to promote argumentative reasoning. The eye movement analysis confirmed a close relation between visual attention to the data-related information and reasoning performance.

Yang Yang Qin Yan

Examine Chinese In-service Science Teachers' Views of Nature of Science

In order to understand the possible changes of in-service science teachers' view of nature of science (NOS) under the influence of literacy-centered reform in science education in China, this study surveyed 152 Chinese in-service science teachers' by using Lederman's instrument of VNOS-D+. Overall, teachers' view of NOS was low. A considerable number of science teachers holding a more native view in most NOS dimensions, such as Subjectivity and Creativity. Understanding of Creativity seemed to be the most difficult part, while the Tentativeness of science was the easiest one to understand. Teaching experience, teaching qualification, school type, and school area had no relationship with science teachers' view towards NOS.

Hamdican Yildirim Sevinc Gelmez Burakgazi

An Investigation of Pre-Service Teachers' Self-Efficacy Perceptions for STEM Integration

In this study, it was aimed to determine the self-efficacy levels of teacher candidates who are studying in the fields of teaching related to STEM. Therefore, a scale was developed by the researchers. The pilot study of the scale was carried out with 200 senior pre-service teachers in STEM-related teaching departments of three major state universities in Turkey. The findings of the pilot study showed us that the data can be interpreted under five factors. These are: STEM awareness and interest, mathematics knowledge, engineering and engineering design process, teaching strategies, and use of technology. Then, another study conducted with 190 pre-service senior teachers in STEM-related teaching departments of one major state university in Turkey, to provide evidence for the construct validity. The results showed that the scale had high reliability (Cronbach's $\alpha = 0.90$) and valid scores. Series of Mann–Whitney U and Kruskal–Wallis H Test had conducted to interpret data. Differences were observed between the teaching strategies of the 21st century teacher candidates and their STEM awareness according to the gender variable. Also, results have shown us that participating in STEM-related activities positively affects STEM awareness and interest, knowledge of engineering design processes, and use of technology.

Xinying Yin

An exploration of Chinese Secondary Chemistry Teachers' Conceptions of Culturally Relevant Science Teaching

While culturally relevant science teaching has been explored in the U.S. and some other countries in the effort to make science learning accessible for all students, it has not been explored in China. Chinese science education has its unique characteristics, including Chinese traditional culture and modern advancement as well as the seemingly homogenous but actually diverse student groups and inequities existing among different student groups. The objective of this study is to understand Chinese secondary

chemistry teachers' conceptions and concerns related to culturally relevant pedagogy through a short course focusing on culturally relevant science teaching. Results show that this short course had a positive influence on these teachers' conceptions of culturally relevant teaching. This intervention raised the teachers' awareness of the role of students' cultural background in science teaching and how science teaching should integrate students' cultural background. The teachers also shared their concerns about implementing culturally relevant teaching in their classrooms, such as the pressure to prepare students for exams, the challenge to change how students learn and how they teach, and limited instructional time and resources. Implications for Chinese science education and understandings of culturally relevant science teaching in the particular context are discussed.

Ella Yonai Ron Blonder

An adaptive design of a remote SEM authentic outreach activity

Before March 2020, with the outbreak of the Covid-19 pandemic, compared with more traditional approaches for learning science, remote science instruction was only moderately developed and implemented. Since the outbreak, however, most studies, specifically outreach activities in a research or academic setting, were halted. Therefore, the need for developing remote learning experiences and teaching/learning strategies was raised. The current study applied a design-based approach to transform an existing outreach science activity using a scanning electron microscope (SEM) from face-to-face (f2f) learning to remote mode while preserving the authentic nature of the activity. The remote activity includes the remote operation of the SEM by the participants. Teachers experienced the remote activity, and data were collected using observations, short interviews, and a quantitative questionnaire regarding the perceived authenticity of the activity. The results suggest the positive potential of the remote mode in learning contemporary scientific content. Emerging advantages of the remote activities can adequately provide the social aspects of communication needed with scientists; these social aspects are essential aspects of an authentic learning experience.

Susan Yoon Katherine Miller

Developing a Coherent Understanding of Biology Through a Complex Systems Lens

The science education community acknowledges the importance of integrating learning about complex systems and adopting a system thinking approach as part of the effort to prepare scientifically literate citizens. However, accumulating research in the past years has clearly shown that teachers and students alike face various challenges engaging in aspects of system thinking. One of the prominent challenges includes the difficulty of addressing underlying mechanisms that account for a system's behavior. In this paper set, an international effort is made to present different tools and strategies that can serve to elicit some of the underlying mechanistic reasoning teachers and students use to make sense of complex systems. We show how system dynamics models, agent-based models, and concept maps can be used to elicit students' mechanistic reasoning and support it. Our collaborative work provides an opportunity to learn about different tools and the affordances they provide, both for characterizing mechanistic

reasoning in the context of complex systems, and supporting teachers and students in making sense of complex phenomena using system thinking aspects.

Hye Sun You Seounghun Lee

Bayesian versus Frequentist Estimation for Item Response Theory (IRT) Models of Interdisciplinary Science Assessment

Natural phenomena and scientific issues are intrinsically interdisciplinary (ID). In this trend, ID assessments to measure students' ID understanding have been developed by several scholars. You et al. (2019) developed the Interdisciplinary Science Assessment for Carbon Cycling (ISACC) to assess ID understanding of the high school and college students in integrating knowledge from different science disciplines to explain a scientific phenomenon, global carbon cycling. The ISACC were analyzed to examine construct validity using traditional item response theory (IRT) models. The current study was motivated by the desire to reveal the difference in IRT analysis results of the ISACC using a Bayesian approach to compare with the results using the traditional approach. In the Bayesian approach, prior distributions on the item parameter and their likelihood from the current data were combined into posterior distributions. The Bayesian models tend to be more toward the center of the distribution than the conventional models and the models are likely to estimate the difficulty of the items to be easier than the traditional models. Unfortunately, the Bayesian approach is scarcely utilized in science education. The results of the study imply additional research for the development and validation of interdisciplinary science assessments through strong psychometric properties.

Hye Sun You Sunyoung Park

What Works in K-12 STEM Professional Development Programs?: A Meta-Analysis of its Impacts on Teachers and Students

Previous teacher professional development (PD) studies have rarely focused on synthesizing what extent the PD programs effectively influence the teachers' content knowledge and pedagogical quality, and further improve students' academic performance in K-12 STEM education. This meta-analysis study aims to evaluate the aggregate effect of STEM PD programs. A total of 852 effect sizes were calculated in 110 studies published between 2010 and 2021. The overall effect size was .73 which is a large effect size on the PD effectiveness (S.E = 0.055, p < .001). Substantial heterogeneity of the effect sizes was observed, which was moderated by PD dosage hours and grade levels. The pooled effect size is getting larger when the program spent larger than 80 hours. Additionally, if the study focused on the specific grade-level such as middle school group or high school group as their target population, the magnitude of the effectiveness of PD is larger than the combination of different grade-level groups. This study provides insights into education research and policy communities to understand PD research and to ensure how PD can be designed and implemented so that student performance improves.

David B. Zandvliet

Places of Learning: Case studies on selected learning environments during COVID

The notion of a place-based education has been described by Soble (1993; 1996) and others have expanded these ideas (Grunewald, 2003; Hutchison, 2004; Orr, 1992, 1994; Thomashow, 1996; Woodhouse & Knapp, 2000). Describing what constitutes a place-based education becomes clouded partly due to the multifaceted and interdisciplinary nature of the literature where this notion resides. Grunewald (2003) writes that place-based learning connects theories of experiential learning, contextual learning, problem-based learning, constructivism, outdoor education, indigenous education and environmental education. This paper relates how learning environment methodologies can be employed in place-based and teacher-lead action-research studies. The earlier developed 'PLACES' instrument have helped in guiding our action research efforts. Learning environment studies also seek to describe contexts and identify empirical relationships among curriculum, teaching practices, and physical environmental variables (Blocher, 1978; Jamieson, 2003; Oblinger, 2006). Disciplines exploring this relationship between the environment and learning include Science Education, Environmental Psychology, Campus Ecology, Architecture, as well as inter- or multi-disciplinary fields of study such as Environmental or Place-based forms of education (Banning, 1988; Bell, Greene, Fisher & Baum, 1996; Kenney, Dumont & Kenney, 2005). In this study we highlight a number of unique case studies of place-based and blended learning environments that occurred during within postsecondary environmental education coures during COVID times. These studies highlight the variability of learning environments that students experiences during this unique time frame and offer unique insights for learning environment studies.

Laura Zangori Laura B Cole

Exploring 6th-Grade Students Model-Based Reasoning about Energy Flow Between Societal and Earth Systems

While there is an extensive literature base on the energy ideas students hold, there are few studies that examine how students use scientific modeling to conceptualize the interrelationships between societal and Earth systems or how students consider the ways that societal energy systems interact with natural energy systems. This exploratory project is situated in this space. We explored how incoming 6th-grade students' (aged 11 - 12) conceptualized energy flow within and across their school building and the surrounding environment within their models and used their models to reason about these relationships (i.e. model-based reasoning or MBR). We report our baseline findings the students held at the start of 6th-grade prior to experiencing any energy curriculum. Our research question was: what are incoming 6th-grade students MBR about energy flow between their school building and the surrounding environment? We collected MBR data from the classrooms of five 6th-grade teachers from the same school district within a small Midwestern city. We analyzed the data quantitatively and qualitatively. Findings highlight the students' ideas about energy flow which includes viewing energy used in human systems as separate from energy in natural systems (such as a food chain). Implications for future work are discussed.

Dana L Zeidler Judith S Lederman

Global Perspectives from the Handbook of Research on Science Education, Volume III

The Handbook of Research on Science Education, Volume II, published in 2014, has arguably had one of the largest impacts on informing research, teaching, learning and policy, as any one publication in the field. Since that time, there has been a meteoritic rise in research in the field. Over the last two years, scholars have combed the vast array of literature since the publication of Volume II to the present and produced an authoritative synthesis and analysis of research in the field, culminating in the Handbook of Research on Science Education, Volume III, having a publication date of late 2022. There are six overarching sections representing 40 chapters in this volume that speak to researchers and educators alike on the current state of the art in science education research and sets the stage for likely fruitful future directions. In this interactive symposium, our goal is to expose participants to these themes and issues through min-discussions and generate interest and further awareness in these represented global perspectives.

Xiaoming Zhai Joseph S. Krajcik

AI-Based Innovative Assessments in Science

Recent development of Artificial Intelligence (AI), especially machine learning (ML) which is a subset of AI, has shown great potential to innovate traditional assessment practices by significantly improving the construct complexity, assessment functionality, and automaticity using AI-based automatic scoring. We thus propose a symposium, including six presentations, focusing on the development and use of AI-based automatically scored assessments for complex performances associated with science teaching and learning, including scientific modeling, argumentation, learning progression of energy, teachers' perception of AI-driven technologies in science classrooms, and design of automatic scoring reports to support teachers' use of AI-based scores in the classroom. The contributors to this session include representatives of the United States' largest educational organizations and major research universities, as well as leading institutions in Europe and Asia. The symposium will examine both the potential and challenges of AI-based assessments in science, facilitating classroom assessment practices to meet the vision of the Framework for K-12 Science Education.

Yang Zhang April Lynn Luehmann

COVID Connects Us: Tensions and Celebrations

COVID-19 has impacted nearly every aspect of life in the US and across the globe. This pandemic presents an example of why scientific literacy, conceptualized broadly to include science concepts, the nature of scientific evidence, and ideas about how science works, is so critical. We contend that it is essential for the spaces of science teaching and learning to be spaces in which complex issues like the COVID pandemic are explored. We contend that the science education community has a key role to play

in supporting expanding dialogues and learning about critical societal issues particularly those, like the COVID crisis, which are so critically connected with science. This paper set features work from five research teams which took up the challenge of responding to the pandemic through science education. The researchers come together here to share some of the ways in which science education has been leveraged in the midst of the COVID crisis. The goal of the session is to surface what the science education community has learned through the current crisis, critical research directions that are needed, and how the community can position itself for effectively responding to the next global crisis that will inevitably emerge.

Lexie Zhao Amanda N. Peel

Student perceptions of computational thinking practices in a CT-integrated environmental science unit

Integrating computational thinking into science curriculum can deepen learning of science content and broaden participation in CT fields. This study uses a taxonomy of CT practices in STEM to frame the iterative design of an environmental science unit. The investigation focused on student perceptions of the CT-integrated unit to better inform the next iteration of this unit. On average, students' attitudes shifted negatively after the unit, but students differ in their perceptions of coding. From an iterative design perspective, we need to understand these perspectives to revise the lesson. Since students' perceptions shape their engagement and interest in continuing in computing-related endeavors, it is important to support comfort and confidence. Potential reasons for attitudinal shifts and implications are discussed.

Michal Zion Guly Ortal-Ivry

Fostering Environmental Literacy through Engagement in Self-Regulation Learning Processes

The goal of this research is to examine the contribution of self-regulation learning (SRL) to the development of environmental literacy (EL). SRL can promote environmental skills at the core of EL, especially when students are faced with complex environmental conflicts. We hypothesize a positive connection between the development of EL and SRL-guided learning. We examined the impact of SRL guidance, provided during an environmental collaborative inquiry-based learning on students' references to the different strands of EL, as well as their level of references for each strand. 111 college students divided into two groups, the EnSRL (Environment SRL), and the EnCr (Environment Control). Both groups participated in the course Making an environmental difference, but differed in the addition of SRL guidance to the EnSRL group. In-depth qualitative and quantitative analyses were carried out to examine students' references to the EL strands as expressed in the learning products. The analysis reinforced the hypothesis that explicit SRL guidance contributed to the overall level of EL, and to the development of EL, and establish a theoretical connection between SRL guidance and EL.

Sarah Maria Zoechling Julia Woithe

Students' Types of Interest in Physics

Given the central importance of increasing students' interest as a goal of physics education in national and international science standards, empirical support for the theoretical description of interest is essential. Previous studies about students' interest in physics did not include modern physics contents. Furthermore, the focus has been on gender issues of physics education, which may increase the perception of gender differences. Thus, our research project examines what matters when increasing students' interest in classical and modern physics contents. We investigate which aspects of physics German-speaking grade-9 students (aged 14 to 16 years) are interested in and whether they can be categorised into different interest types based on their interest profiles and their physics-related self-concept. We conducted a cross-cohort online study (N=746). Mixed Rasch analysis revealed that the sample can be categorised into three interest types. Moreover, our findings support claims from the theoretical and empirical literature, stating that the majority of students are interested in physics only when set in a context related to humans, socio-scientific issues, and everyday applications. Knowing the students' types of interest in physics, will enable educators to design their learning activities accordingly, and thus to increase their students' interests.

Vivian A Zohery Ananya Matewos

Examining Science Engagement: Epistemic Operations and Agentic Practices During Argumentation

Socio-scientific phenomena, such as climate change are challenging to both teach and learn. In the present study, we identified and characterized cognitive engagement and agentic practices during science classroom discourse. We then examined how agentic practices related to epistemic operations (cognitive engagement). We ended by considering how such practices distributed engagement among students in a small group. We used a qualitative research methodology to analyze our data of one middle school classroom's science class discourse. We found that students tended to demonstrate EOs of questioning along with reasoning, justifying, and recalling evidence most often. This was preceded by agentic operations of facilitating and monitoring the group's understanding of the topic at hand. Reasoning as an EO was particularly connected to the flow of understanding and the directionality of conceptual construction of knowledge for the group, and aligned often with agentic practices. Finally, we found that individual roles within the group shifted over time to be more broadly participatory across both EO's and agentic practices, reflecting shared cognitive engagement and distributed agency indicating collective engagement within the group.

Majd Zouda Dimitris Tsoubaris

Among the Possible, the Is and the Ought: Constructs of 'Micro-Sociotechnical Imaginaries'

Humanity is facing myriad 'wicked' problems — including those linked to climate, surveillance systems, manufactured foods, habitats and related species diversities — associated with capitalism-influenced fields of science and technology. Assuming capitalist manipulation of public knowledge and subjectivities

and learners' diverse abilities, cultural and social capital, etc., the five papers in this Related Paper set provide theoretical and empirically-based evaluations of a constructivism-informed pegagogical schema (ReActions) that prioritizes direct teacher instruction of often difficult-to-discover conceptions in relationships among science and technology and societies and environments and education encouraging and enabling students to independently implement sociopolitical actions to overcome harms like those above of their concern. The five papers appear to support Unity and Inclusion for Global Scientific Literacy through qualitative action research to apply and evaluate the ReActions schema in multiple educational contexts (primary, secondary & tertiary), drawing from Science & Technology Studies [STS]) and the arts to understand possible alignments among numerous 'actants' within a growing dispositif (i.e., purposeful machine-like actor-networks) that may promote ecojustice outcomes, like: communitycentred (vs. individualistic) goals; ecocentric (vs. anthropocentric) worldviews; tempered (vs. continuous) change; and, intrinsic (vs. exchange) values. STS conceptions apparently aiding this work include: sociotechnical imaginaries; dispositifs; phenomena-semiotic relationships; (de-)punctualization; and, governmentality.

Cathy Zozakiewicz Jill A. Wertheim

Examining the impact of using pilot data to support teachers in designing high quality three-dimensional performance assessments

The need for high quality performance assessments to support NGSS is clear. The problem in the field relates to traditional approaches to training educators to design high-quality assessments. Most trainings too often begin and end with drafting an assessment. We believe this falls short of the goal of designing any high-quality assessment. Instead, we argue the iterative process of designing assessments is essential. To support educators in learning to use principled design to iteratively develop high quality assessments, we developed a series of four free online courses. This study followed two urban districts piloting the courses, who wanted to support educators in designing high quality performance assessments to embed in their local NGSS curriculum. The study investigated what impact the iterative process and course design had on the assessment development process. Findings based on analysis of assessments artifacts indicated improvement in three key areas: promoting student use of dimensions to make sense of phenomenon, developing storylines so task elements built cohesively, and including scaffolds to support students in demonstrating their three-dimensional learning.

Lynne Zummo

Decisions for Our Future: Learning through Collaborative Civic Decision-Making in a Digital Climate Simulation

Many natural history museums are exploring new ways to engage visitors about complex socio-scientific issues, such as climate change. At the same time, museums are embracing technology, such as virtual reality and other tools that similarly foster interest and motivation. This study offers an analysis of visitor experience in an innovative, collaborative, digital simulation that engages learners in civic decision making. Situated at a natural history museum in the US, the studied digital experience engages

leaners in cooperatively making decisions about energy, food, and recreational resources, all while documenting the impact of decisions on the climate. Applying sociocultural notions of discourse and learning, we analyze audio data to identify local and global discourses drawn on as resources for meaning making by learners in the experience. We also document moments of expression of agency and identity work done by participants while interacting with the simulation. This research builds knowledge around social interaction and meaning making in a digital, interactive museum-based experience about a contentious socio-scientific issue. It also offers insight on design of digital climate simulations as technological tools that go beyond generating interest and motivation to engage learners in critical thought and decision making.

Lynne Zummo Emma C Gargroetzi

Theorizing Science-Civic Practices: Youth Adaptation and Remixing of Science Practices within Digital Civic Participation

During the 2020 US presidential campaign, youth engaged civically to reimagine their turbulent worlds, publishing media via the website Let's Talk about Election 2020. We examined 300 pieces of youth-produced media about either climate change or COVID-19, two prominent and contentious socio-scientific issues. Our goal was to build knowledge around how youth use data-oriented science practices in their civic lives—how they adapt scientific ways of interpreting the world through data, how they mix and integrate science with other epistemologies, and what data practices they choose to apply in civic communication. As a theoretical lens, we use sociocultural concepts of practices, language, and discourse. Through a combination of deductive and inductive coding, we identified the ways in which youth engaged in data-oriented science practices and adapted them to meet their own locally relevant needs within civic participation. We found that youth often skillfully integrated traditional ideas of science practices with other knowledges, such as those of place, politics, and youth culture to produce civic media. From this analysis, we begin to theorize science-civic practices, or the locally-meaningful ways of participating and making meaning in the civic world that interweave science practices with other epistemologies.

Shani Zur Tali Tal

How do excellent STEM teachers design and implement best practice of inquiry-based learning?

In this proposal, we present our research of best practices of Inquiry-based learning. Inquiry-based learning is a well-known learning strategy that could enhance student understanding of science and nature of science. However, when inquiry is being taught in a structured and highly controlled manner, students might not enjoy its potential benefits. It is important to understand the aspects that could help inquiry learning in the broad sense, meaning going beyond the experimental variable control model and focusing on the epistemic aspects. Based on prior research that showed mainly challenges teachers face, we investigated eight exemplary teachers who conduct a unique and outstanding open-ended inquiry. We used a naturalistic interpretative approach and discourse analysis to examine teachers' views and aspects of their professional identity. We investigated their choices and action and how they contribute

to successful design and implementation of inquiry-learning. We highlight three main aspects: (1) teachers' past experiences as learners contribute to shaping their educational goals and values (2) teachers' view of their students as individuals (3) teachers' confidence due to their excellent content knowledge. We highlight teachers' choices and actions regarding inquiry design and implementation as well. Implications for teachers, teacher educators, and policymakers are discussed.