Supporting the Implementation of *NGSS* through Research: **Curriculum Materials**

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Curriculum materials are of critical importance as our nation moves forward with the implementation of the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States, 2013). The new standards fuse scientific and engineering practices, disciplinary core ideas, and crosscutting concepts; trace learning progressions over students' development; and set goals for meaningful learning of *all* students in *all* U.S. schools. These standards set a high bar for teachers and students, and curriculum materials provide one crucial form of support for meeting these new expectations. In this position paper, we define "curriculum materials" as the representational tools (often published) that teachers use to support and guide their teaching practice. The *NGSS* outline the proposed *curricular goals*—what is to be taught—and *curriculum materials* provide support for how to teach them, including a structure and flow for specific content, recommended instructional strategies, and suggested experiences for the learners. In this position paper, we (a) briefly synthesize research related to curriculum materials and their role in supporting teaching and learning; (b) delineate current perspectives on characteristics of effective curriculum materials; and (c) use that research and those perspectives to substantiate our position that our nation needs models of next generation science curriculum materials to reflect and support the emphases of the *Next Generation Science Standards* and improve science learning opportunities for all students.

Curriculum materials have long been put forward as a vehicle for reform (Ball & Cohen, 1996). Next generation curriculum materials—which will take many forms including traditional textbooks, e-books, online materials that make use of large data bases, multimedia experiences, and teacher guides with kits—will directly shape students' opportunities to learn the *NGSS* by structuring sequences of learning activities in which students engage with the support of a teacher. Next generation curriculum materials will also support teachers' own growth, learning, and development in relation to *NGSS*.

Curriculum materials cannot be considered in isolation. Teachers' instruction and assessment, for example, are inextricably linked with the curriculum materials to which they have access. The question of access highlights the relation between curriculum materials and education policy, in that access is not only a function of what materials exist, but also of what materials are adopted by states and districts. Further, curriculum materials—even ones designed with the intention of supporting teachers' learning—require supportive school and district structures and policies, such as collaborative planning and ongoing high quality professional development. Indeed, once next generation curriculum materials are developed, teachers will need both targeted and sustained support to become proficient users of these new curriculum materials. Furthermore, curriculum materials cannot, do not, and should not "teacher proof" classroom teaching. Teaching is a profession, and teachers must have agency to make informed decisions about how to plan for and enact instruction in their classrooms. Curriculum materials, however, can serve as a critical *tool* for that decision-making work; a tool, that when used effectively, can help teachers engage in reform-oriented science teaching. The release of the *NGSS* can facilitate our thinking about the role of curriculum materials.

What role do curriculum materials currently play in K-12 schools? Teachers at all grade levels routinely use curriculum materials (Banilower et al., 2013) and engage in what Remillard (2005) refers to as a "participatory relationship" with the materials: they interact with curriculum materials, and this interaction shapes their teaching, while at the same time, who the teacher is as an individual shapes how s/he engages with the materials.

Curriculum materials, while ubiquitous in K-12 settings, are used differently in elementary and secondary science classrooms, because those instructional contexts are so different. At the elementary level, science may be inconsistently or infrequently taught, the teachers are not typically science specialists, and science instruction tends to be activity-oriented at the expense of sense making (Banilower et al., 2013). In these contexts, curriculum materials can serve as an effective tool for supporting more consistent and coherent science instruction, supporting teachers in developing important conceptual knowledge of science, and framing science learning as a sense-making activity. At the secondary level, typical science instruction tends to be more fact-oriented, often relying on lecture to convey large volumes of information, with laboratory experiences serving the purpose of verifying key ideas—that is, the instruction is still not oriented toward sense making (Banilower et al., 2013). Well-designed curriculum materials have the potential to provide secondary teachers with a vision of how to successfully integrate disciplinary concepts, crosscutting concepts, and practices, as well as relate instruction to standards and assessments. Thus, next generation curriculum materials that reflect the *NGSS* can serve as a powerful tool for supporting both elementary and secondary science teachers in rethinking their pedagogical goals, but only through the simultaneous development of supportive materials adoption and teacher learning policies, as explored in other position papers in this set.

As a field, we have reached some consensus about the characteristics of effective curriculum materials. By "effective," we mean likely to support robust learning of all students. Effective science curriculum materials must be developed with attention to what we know about how people learn science (Bransford, Brown, & Cocking, 1999). Learners construct understandings building on prior knowledge, through experience with natural phenomena and engagement with others. Each person's understandings are shaped by his or her cultural, linguistic, and economic backgrounds and contexts among other factors. Increasing cultural, linguistic, and economic diversity, therefore, implies increasingly diverse understandings, challenging some of what we think we know about how people learn. Our understandings of learning theory must continue to grow more nuanced, and as a result, next generation curriculum development and instructional design processes need to become more complex, as well.

Effective curriculum materials are coherent, rigorous, and focused on big ideas. These materials have lessons sequenced to unfold sensibly, with ideas building on one another toward the development of an integrated understanding and support for students to see the coherence (Roseman, Linn, & Koppal, 2008). Coherence may be particularly important in light of the high degree of student and teacher mobility in many U.S. schools. Adopting similar curricular goals across the nation may reduce some of the struggles faced by an increasingly transitory population of both students and teachers. Coherent curriculum materials built around the *NGSS* can ease the burden as teachers and students move from school to school. Indeed, with the publication of *NGSS*, this drive toward coherence, rigor, and focus on big ideas manifests through alignment with these standards. In other words, the standards themselves are aimed at increasing the coherence and rigor of U.S. science instruction and the *NGSS* purport to drive toward students' understandings of big ideas in science. Further, given the reality that standards-driven accountability pressures are typically greater in “low performing” schools that disproportionately educate students of color and students living in poverty, the issues of curricular coherence and rigor become issues of equity as well.

A second key characteristic of effective curriculum materials is that they must provide and support opportunities for students' sense making. Typical U.S. classrooms at both the elementary and secondary level, as described above, tend not to place sufficient emphasis on sense making. It has been hypothesized that this is due to lack of instructional time devoted to science, fragility of teacher knowledge, and lack of confidence in students’ abilities to engage in sophisticated thinking. However, without a focus on sense making, instruction can devolve into a listing of facts or meaningless engagement in a series of activities. Further, a focus on sense making rather than acquisition of facts fosters a fundamentally different language learning environment in the science classroom. Teaching for sense making promotes a wide range of language-rich classroom discourse patterns while teaching for fact acquisition promotes a traditional discourse pattern that is language-restrictive. While a language-rich science classroom benefits all students, it is particularly important for English-language learners and other students who have more limited engagement with academic language outside of the classroom context. The emphasis in the *NGSS* on science and engineering practices such as constructing scientific explanations, engaging in argument from evidence, developing and using models, and analyzing and interpreting data will necessarily push the need for language-rich sense making to the forefront.

A third key characteristic of effective curriculum materials is that they must engage students' lived experiences. All students experience science and engineering in practical ways many times every day. School science curriculum materials often come up short, however, in making these connections in ways that engage students’ interest and curiosity. Further, there is growing evidence for the importance of culturally relevant and place-based pedagogy as engaging approaches for reaching students who do not necessarily buy in to the educational capital argument for the value of academic learning. Many of today’s students are looking for more immediate justifications for why learning science is something they should take seriously. Next generation curriculum materials can and should do more to make scientific phenomena relevant for students.

A final key characteristic of effective curriculum materials is that they are educative for teachers as well as students—that is, they are designed with the intent of supporting teacher learning as well as student learning (Davis & Krajcik, 2005). Educative curriculum materials are intended to support teachers in developing a stronger knowledge base and practice base. For example, educative curriculum materials can support teachers in recognizing the coherence of the science ideas at play in a unit—in other words, how all of the ideas are connected to one another and build on one another through the lessons. Educative curriculum materials can also provide "images of the possible," through vignettes describing teachers' adaptations of the lessons, examples of real student work, and sample teacher comments and discourse. Such images can help support teachers in setting higher expectations for their students. For example, if teachers from a high-needs school see sample student work drawn from a similar instructional context, they may be more likely to recognize that their students, too, are able to engage in the higher-demand instruction, and thus be more likely to work to enact it. Furthermore, we can use educative curriculum materials as one form of support for teachers who are less well-prepared or newer to the profession. These teachers are more likely to be teaching students from disadvantaged backgrounds. Next generation curriculum materials will need to support all teachers as well as all students.

As a nation, we have made a substantial investment of both private and public funds in the development of curriculum materials over the last 50 years. Does the arrival of *NGSS* mean that those materials are no longer valuable? Is it possible to retrofit extant materials in ways that meet the goals of *NGSS*? Should we develop supplemental units that emphasize and illustrate some of the newer aspects of the *NGSS* such as the practices of science or connections to engineering? Should we invest in completely new sets of curriculum materials? These are open questions with multiple solutions. It is clear, however, that to meet the needs of the nation, next generation curriculum materials *must* build from what we know about curriculum materials and build toward the vision of the *NGSS*.

We take the position that with the pending implementation of *NGSS* comes the need for models of next generation curriculum materials. Science education in the U.S. will benefit from the development of model curriculum materials that are consciously designed to reflect the emphases of the *NGSS*, as well as integrating what we know about improving learning opportunities for all students by being responsive to the changing cultural, linguistic, and economic demographic realities of the current and future student populations in our schools. This means that next generation curriculum materials should be:

1. Research-based in both design and development. High-quality curriculum materials are not market-driven. They are designed, developed, and field-tested using data about how students learn and how teachers teach. The development process should include explicit and overt attention to student thinking, such as through the use of robust formative assessment data, which can be tied to teachers' practices or enactments of the relationship between the curriculum materials, standards, and the goals for their students' learning. An iterative design process that includes input and reviews from scientists and educators is required if these models are going to be effective in improving science literacy. This is not a process that relies on pressures from popular political or social trends.
2. Able to generate research findings. This includes integrating mechanisms for data collection to determine how the curriculum models are being implemented and what students are learning.
3. Well-aligned with the framework and standards. The models should bring the *NGSS* to life for teachers and exemplify putting the standards into action in the classroom. Specifically, the design of next generation curriculum materials must:
    - attend to the amount of content students can *learn* (not just the amount teachers can cover)

- incorporate crosscutting concepts in ways that are purposeful and integrative, rather than passing references
- incorporate opportunities for meaningful engagement in the scientific and engineering practices in ways that do justice to the disciplines of science and engineering and concomitantly promote students' capacity to see and apply these practices in and out of school
- support teachers in developing a vision for how they can better understand and work toward the intent of *NGSS*

4. Able to address the full range of students' learning needs. For example, next generation curriculum materials must effectively support the linguistic and mathematical learning called for in the *Common Core State Standards* just as language arts and mathematics instruction should support scientific thinking and communicating. At the same time, next generation curriculum materials must allow for and foster localized and culturally relevant connections to support all students.
5. Coordinated with formative and summative assessments, including high-stakes tests. High-quality curriculum implemented well will result in student learning. All assessment should be aligned with the characteristics of this type of curriculum so that teachers no longer feel compelled to “teach to the test” as a separate activity (a point taken up more fully in the position paper on assessment and *NGSS*).
6. Reflective of the extant research about effective curriculum materials. Potential developers need to be open to adapting and revising well-researched, effective materials that can be aligned with the *NGSS*.
7. Able to account for a non-print paradigm for curriculum and the desire of students and teachers to be producers as well as consumers of content. This means that we need to generate models of online, print, and blended curriculum materials that reflect the research on learning, teaching, and curriculum.
8. Integrated with the continuum of programs for K-12 teacher development (preservice through inservice). Regardless of where they are in their career development, teachers should have the opportunity to analyze and understand the nature of and practice using high-quality next generation curriculum materials, and learn to use them. As model curriculum materials are developed, we need to disseminate the models throughout the teacher education system.
9. Funded by organizations that are committed to a research-based development process so that the materials address the needs of learners and teachers and promote science literacy as defined by the *NGSS*. If we leave the adaptation and development of curriculum materials to the pressures of the marketplace we are unlikely to see the changes that are needed.

Other challenges include working to ensure the adoption of these next generation curriculum materials and pushing to extend the amount of time spent on school science. As we move toward development of next generation curriculum materials, we will continue to create and refine the tools that teachers and others in the educational system need for putting the *Next Generation Science Standards* into practice.

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