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Cognitive-Science Interventions Improved Middle School Science Learning; Teacher Content Knowledge PD Did Not

Steven L. Kramer, Janie Scull, Andrew Porter, Christine M. Massey, F. Joseph Merlino, John Y. Baker

OVERVIEW: Students in science classrooms that used three cognitive-science principles learned more science than either: A) Students whose teachers participated in PD to increase their content knowledge; or B) Students in Business-as-usual classrooms.

AUDIENCE: Administrators (K-12), District science coordinators, Doctoral advisors, Environmental educators, Formal educators, Grant funders, Instructional designers, K-12 science teachers, Policymakers, Professional development providers, Researchers/Researcher supervisors, Science education leaders, Secondary science teachers, Teacher educators, Biology educators, Chemistry educators, Physics educators, Earth science educators, STEM educators

KEY POINTS

- Cognitive science principles were: contrasting cases; diagrammatic reasoning; and spaced testing.
- Classrooms used the inquiry focused Full Option Science System (FOSS) science curriculum.
- The interventions were implemented for three FOSS units, each with 50 days of instruction.
- For each unit taught, treatment teachers participated in 18 hours of treatment-specific professional development followed by 16 hours of support in professional learning communities across two years.
- The cluster-randomized controlled trial involved 89 schools, 253 teachers, and 20,591 students.

INTRODUCTION: It was unclear whether laboratory-tested cognitive-science interventions would continue to have positive effects when implemented in real classrooms by ordinary teachers over an extended period of time. Separately, it is common sense that helping science teachers learn more about the content they will be teaching should improve their students' learning—but this had yet to be demonstrated in everyday classrooms. Our large-scale study tested both of these interventions against each other and against a business-as-usual control condition. Volunteer middle schools were randomly assigned to one of the three conditions so we could compare how much science students learned in each condition.

FINDINGS We administered an 18-item end-of-unit content test at the end of each of the FOSS units. The Cognitive Science intervention had a statistically significant small positive impact. Students in the Cognitive Science group scored about 0.16 standard deviations (SD) better than students in the Control group and about 0.13 SD better than students in the Teacher Content Knowledge group. Assuming normally distributed data, effects of these magnitudes would move a student from the 50th percentile up to the 56th or 55th percentile, respectively, on one of our unit tests. While the data indicates that students at most prior achievement levels would benefit from the Cognitive Science treatment, the intervention was more effective for students with higher prior-achievement scores in math and reading than for students with lower prior-achievement scores. We detected no difference in science learning between students in the Teacher Content Knowledge intervention group and students in the no-intervention Control group. We also did not detect any effects of the content-knowledge intervention on teachers' tested content knowledge, although this latter finding may have been caused by relatively low statistical power due to the limited number of teachers tested.

TAKEAWAYS Our results provide confirmation that cognitive science principles developed in the laboratory can continue to have positive, albeit small, impacts on student learning when translated into regular classroom practice. In contrast to these positive findings, focused professional development aimed at improving middle school teachers' content knowledge of the specific science topics they would be teaching did not impact how much science content their students learned. While the current study focused on the hands-on FOSS curriculum, our research center obtained similar findings when using the more traditional Holt curriculum: a small positive effect for implementing Cognitive Science principles, but no effect for PD focused on teacher content knowledge. Based on our results, curriculum developers, policymakers, and educators looking to improve science learning should consider incorporating contrasting cases, support for diagrammatic reasoning, and spaced testing into everyday classroom instruction.

Full Title: Can Either Using Cognitive Science Principles or Improving Teacher Content Knowledge Boost Student Achievement in Middle School Science?