Applying Cognitive Principles to Improve Science and Math Curricula

Chair: Steve Schneider, WestEd
Discussant: Phil Kellman, University of California, Los Angeles

1. **Using research on analogical reasoning, diagrammatic reasoning, and prior knowledge to improve middle school science outcomes.**
Presenter: Nora Newcombe, Temple University

There have often been complaints about the lack of implementation of basic research findings from cognitive science into curricula. We are conducting a large research study to examine whether systematic modification of middle school science curricula using general cognitive science principles can significantly improve student learning in large urban school districts. A team of cognitive scientists is collaborating to systematically modify 3 curriculum units in common textbook for teaching science and 3 curriculum units in a common hands-on science curriculum. The modifications are based primarily on four main principles derived from cognitive science research: contrasting cases setup instruction, visualization conventions and challenges need to be explicitly addressed in instruction, instruction must build upon and address student prior knowledge, and spaced testing improves retention. We describe the foundations of these principles and provide examples of how these principles were used to modify the science curricula. This study presents an opportunity to test the cumulative benefit of basic cognitive science research applied to science education rather than just laboratory demonstrations.

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2. **Applying principles of worked examples, visual mapping, formative assessment, and spacing to improve middle school math outcomes**
Presenter: Jim Pellegrino, University of Illinois, Chicago

Basic research in cognitive science has identified design principles for effective instruction and practice. However, as classroom settings and curricula are very different from the typical research laboratory settings and materials, this substantial knowledge base has had only a limited influence in shaping the design of most K-12 instructional materials and practices. The National Research and Development Center on Cognition and Mathematics Instruction has the goal of redesigning components of a widely used middle school mathematics curriculum – Connected Mathematics Project (CMP) using four primary design principles from the IES Practice Guide (Pashler et al., 2007). These principles include: (1) combining
graphics with verbal descriptions in ways that promote the integration of concepts, (2) structuring practice by interleaving worked samples with new problems to solve, (3) carefully spacing the learning of critical content and skills over time, and (4) using focused feedback on quizzes and homework to promote student learning. We will describe how the principles have been specified and applied to the redesign of the CMP curriculum, and we will report findings from ongoing research studies that inform both cognitive theories and mathematics instruction.

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3. Measuring efficacy of principle-based redesign of science curricula
Presenter: Laura Desimone, University of Pennsylvania

We describe the results of two parallel large-scale randomized control trials designed to test the effects of applying cognitive science principles to particular units in two middle school science curricula: FOSS and Holt. There are three arms per trial, each with approximately 30 schools per arm: 1) the control group, who experience unmodified curricula and no supplemental professional development, 2) the content group, who receive professional development on the content related to the middle school science units, and 3) the cognitive science group, who receive a modified curriculum incorporating cognitive science principles and professional development in content knowledge and cognitive science. We measure student achievement results with two measures: the state standardized achievement test, and a test constructed by the research team to be aligned with the subject-matter content taught in the middle school science units being studied.

To date, there are 91 schools in the FOSS trial (28 in Pittsburgh and 63 in Arizona districts) encompassing 255 teachers, and 92 schools in the Holt trial (in Philadelphia), involving 201 teachers. The number of students participating in each trial is on the order of 7000, though only a subset of these will receive instruction in all three units of the intervention given variation in participating teachers and student mobility. We report interim results on student achievement, teacher content knowledge (as measured by a test the research team constructed), and teachers' instruction (as measured by a self-report survey administered to teachers after they taught each unit that was part of the study).

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