STEM Education:
Educating Teachers for a New World

Babette M. Benken
California State University, Long Beach
Heidi J. Stevenson
University of the Pacific

Our national curriculum is in the midst of reform—it calls for attention to STEM (*Science, Technology, Engineering, and Mathematics*) education and subsequently STEM teacher preparation and professional development. In 2005, the congressionally requested report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (National Academies Press, 2007), made educators aware of and began to address a deep concern about not having enough scientists, engineers, and mathematicians to keep the United States in the forefront of research, innovation, and technology. It argued that a comprehensive and coordinated federal effort is urgently required to bolster the competitiveness and pre-eminence of the United States in these STEM areas. Nationally, it is predicted that 80% of new jobs will require at least some mathematics, science, and engineering, and 50% of the technical workforce will retire soon, making it more important than ever to inspire students in these fields (Wolfram Institute, 2012).

Babette M. Benken is an associate professor in the Department of Mathematics and Statistics and director of graduate studies in the College of Natural Sciences and Mathematics at California State University, Long Beach. Heidi J. Stevenson is an associate professor in the Department of Curriculum and Instruction of the Benerd School of Education at the University of Pacific, Stockton, California. They served as co-guest editors of this issue of Issues in Teacher Education. *Their e-mail addresses are babette.benken@csulb.edu and hstevenson@pacific.edu*

Although the majority of students will not likely pursue STEM-specific careers, they will benefit from STEM literacy in other facets of their lives. As an NRC report on STEM education outlined, individuals require some understanding of the STEM disciplines in order to manage many daily tasks and technology-supported activities (National Research Council, 2011). In the 2010 Report to the President titled *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future*, the President's Council of Advisors on Science and Technology further advanced the demand for transforming K-12 education. They echoed the need for students to have a strong foundation in STEM subjects, with knowledge that they can readily use in both their personal and professional lives. The Report identified the critical role that teachers play in preparing and inspiring students, thereby necessitating the recruitment and education of STEM teachers, as well as a transformation of teacher preparation.

This reform is further fueled by the imminent implementation of the Common Core State Standards for Mathematics (Common Core Standards Initiative, 2010) and the Next Generation of Science Standards (Achieve, 2013). These new standards require that teachers possess deep and flexible understandings of STEM content and how STEM disciplines are connected and integrated across the curriculum, as well as specific pedagogies and tools that support STEM education, particularly for low-achieving learners. For example, the Center for the Future of Teaching and Learning, CFTL (Guha, Shields, Tiffany-Morales, Bland, & Campbell, 2008), urges the need for teacher training and notes that students in schools with lower pass rates on the California high school exit exam are nearly twice as likely to have been taught by underprepared or novice teachers.

Nationally, time devoted to science instruction in the K-6 classroom has declined by at least a third since 2001, with only 50% of teachers spending at least an hour a week, and 16% spending no time at all on science (CCST, 2010). For example, a recent study conducted by the CFTL at WestEd titled *High Hopes, Few Opportunities: The Status of Elementary Science Education*, summarizes research findings on science education in California's elementary schools. They found that children rarely have the opportunity to engage in high-quality science because "the conditions that would support such learning are rarely in place and because very little support infrastructure for science education exists in the state's schools and school districts" (Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011, p. 1). Therefore, it is not surprising that students' performance in science suffers. This year's release of the 2009 National Assessment of Educational Progress (NAEP) results for 8th grade science showed that the overall average score for the nation was only at the Basic Achievement Level (partial mastery of fundamental skills). In some urban and diverse areas, however, results are even less hopeful. In California, for example, the overall average score for 8th grade science fell below the NAEP Basic Achievement Level (NCES, 2011, p. 451). On the 2010 state science standards test, about 45% of 5th grade students scored below the proficient level (Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011).

Algebra has been shown to be a gatekeeper course to advanced study in both mathematics and science (Smith, 1996). However, many students do not successfully complete an algebra course and achievement gaps by ethnicity, as well as other subgroups (e.g., English learners, ELs), are quite sizeable across the nation. Within California, for example, only 23% of all ninth grade students taking an algebra course scored proficient or above in algebra on the annual statewide exam in 2011 (STAR results, California Dept. of Education, 2011). The level of proficiency decreased even further when tracking scores for subgroups of this population (e.g., 11% of ELs and 15% of African American students were proficient or above).

Well-qualified teachers have been shown to make a marked difference in improving student learning (Guha, Shields, Tiffany-Morales, Bland, & Campbell, 2008; Nye, Konstantopoulos, & Hedges, 2004). In California, however, 40% of middle school teachers of Algebra I (presumably the most qualified among the middle school mathematics faculty) do not have a subject matter credential in mathematics and may lack the background and preparation necessary to effectively teach the subject (Esch et al., 2005). The level of high school teacher training is also discouraging; the CFTL (Esch et al., 2005) estimated that 20% of high school mathematics teachers are teaching out of their field of expertise or have not yet completed requirements for a teaching credential. Furthermore, "not only are middle and high school students in desperate need of high quality mathematics teachers, [California's] existing professional development programs that might serve to boost teachers' knowledge and skill in this area are not targeted or designed to do so" (Esch et al., 2005), and the amount of total funds dedicated to professional development has gone down over the past few years, in spite of current pressure on teachers to begin implementing the new standards (Bland et al., 2011). However, few formal mathematics content-focused programs (beyond certification) exist for in-service grade 6-10 teachers who fit this description.

In our highlighted, introductory article, Edward A. Silver and Rachel B. Snider offer suggestions for using existing international assessment content tasks to support teachers in fostering STEM literate students. Their article sets the stage for two major questions discussed in our issue: What does it mean to be STEM literate? and What approaches to teacher preparation are most effective in supporting high-quality STEM instruction? Specifically, in "Using PISA to Stimulate STEM Teacher Professional Learning in the United States: The Case of Mathematics," they illustrate how their project at the University of Michigan has adapted Programme for International Student Assessment, or PISA (OECD, 2013), tasks to help preservice and practicing teachers to focus on building curricular coherence across grades 6-11 in the treatment of topics associated with algebra. Their unique PISA task model offers detailed recommendations to exhibit and foster content and pedagogically rich inquiry with teachers. This process can then extend to expanded teacher analyses of their students' work and classroom discussions focused on understanding content.

Carolyn A. Maher and her colleagues at Rutgers University (Palius, Maher, Hmelo-Silver, & Sigley) similarly explore how using carefully selected mathematical tasks can support teacher learning. In "Teachers Can Learn to Attend to Students' Reasoning Using Videos as a Tool," they describe integrated math and technology interventions that helped K-8 teachers to grow in their ability to recognize forms of mathematical reasoning used by children. This is the first step in promoting practices that emphasize the reasoning and justification demanded by both the new mathematics and science standards (Achieve, 2013; Common Core Standards Initiative, 2010).

In "Where is the "E" in STEM For Young Children? Engineering Design Education in an Elementary Teacher Preparation Program," Daniell DiFrancesca, Carrie Lee, and Ellen McIntyre explore a novel STEM-focused model for teacher development that integrates the engineering design process. They explain how their program at the University of North Carolina at Charlotte incorporates the often-underrepresented "E" (engineering) by building explicit connections among STEM content areas throughout the program and intentionally attending to prospective teachers' attitudes toward engineering. They also describe the program's culminating methods course devoted specifically to the engineering design process.

With a focus on science, as well as academic language and literacy, Sara Tolbert, Trish Stoddart, Edward G. Lyon, and Jorge Solis similarly present a model for initial teacher preparation. In, "The Next Generation Science Standards, Common Core State Standards, and English Learners: Using the SSTELLA Framework to Prepare Preservice Secondary Science Teachers," they offer a unique response to the critical need for teachers to be more proficient at teaching science in a manner that supports the vision of scientific inquiry and attention to literacy in the new standards, as well as teaching STEM academic content to a growing population of English learners.

In their secondary teacher preparation program, Ruth Helen Yopp, Mark W. Ellis, and Martin V. Bonsangue are "Piloting a Co-teaching Model for Mathematics Teacher Preparation: Learning to Teach Together." This innovative model maximizes the potential of collaborative teaching, in which prospective and inservice teachers equally partner to design and implement lessons in high-needs schools. In this article, they describe the generation and study of using this alternative to traditional student teaching for foundational level mathematics (7th grade through geometry).

Extending the discussion beyond what STEM teachers need to know and experience is the work of Alison Castro Superfine and Wenjuan Li at the University of Illinois at Chicago. Their article, which focuses on "Developing Mathematical Knowledge for Teaching Teachers: A Model for the Professional Development of Teacher Educators," outlines how to integrate video and specialized content tasks in ways that can help those who teach mathematics content courses for preservice elementary teachers grow professionally. Through a series of workshops, the participating teacher educators (representing various two- and four-year institutions) were able to engage with mathematical content in new ways, which then translated to expanded ways of preparing elementary teachers to teach math.

In the final article of the themed portion of this issue, "Myths and Motives Behind STEM (Science, Technology, Engineering and Mathematics) Education and the STEM-Worker Shortage Narrative," Heidi J. Stevenson returns to the greater conversation of why STEM and why now. Her critical essay synthesizes multiple bodies of work, which bring into question the accuracy of the STEM-qualified worker shortage and who may be profiting from the current STEM narrative. This discussion provides a new and unique lens that can move the field of teacher education forward as we attempt to navigate new technologies and standards in STEM subjects.

We conclude this special issue with a brief review of a guide intended for teachers, administrators, and policy makers to improve instructional practices related to U.S. STEM education titled *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (National Research Council, 2011). In her review, Torrey Trust highlights four recommendations made by the authors, as well as the implications and limitations of those suggestions.

This special issue showcases forward thinkers in the field who provide teacher educators with a vision of change and relevant resources to implement best practices in STEM research and practice, with examples representing all stages of the learning to teach continuum from initial preparation through induction and ongoing professional development. We need new approaches to and designs for teacher education that place emphasis on STEM education and integration, as well as research that explores the role that STEM education can, and should, play within our evolving national curriculum and system of teacher preparation.

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Journal Editors' Addendum

Two additional manuscripts and one book review are included in this issue of *Issues in Teacher Education*. The first, "From 'Urban' to Urban: Engaging Schools and Communities in Teacher Education" by Ruanda Garth McCullough and Ann Marie Ryan, examines the impact of a new course that broadens a teacher education program in preparing teachers to engage in urban schools and communities.

The second, "Using a Participant Pool to Gather Data in a Teacher Education Program: The Course of One School's Efforts" by Peter Wiens, reports on the use of a university teacher education department's creation and implementation of a "participant data pool" to collect and manage certain types of data on teacher education students.

Finally, Cyndi Mottola Poole writes a compelling review of *Preparing Change Agents for the Classroom: From Paradigm to Practice* by Jill Cole (2012). This book challenges teacher educators to embrace constructivism as a teaching philosophy and in their teacher preparation classes in order to encourage "change agency" in teacher candidates.

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—Joel A. Colbert & Suzanne SooHoo,
Co-Editors, *Issues in Teacher Education*