Mathematics Teaching and Learning at a STEM-Focused High School
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Study Goals and Purpose
As part of a larger project, this study explored how a mathematics teacher planned and taught in an innovative Science Technology Engineering and Mathematics (STEM)-focused high school in order to identify high-achievement practices in both terms of practices that develop teachers’ understanding of curriculum (including standards and resources) and in terms of how particular uses of curriculum materials may lead to changes in instructional practices and students’ learning.

Rationale and Theoretical Perspectives
Educators recognize a need to identify high-achievement teaching practices (Ball et al., 2009), and models that result in improved student learning of mathematics. In particular, we need a better understanding of (1) teachers’ uses of curriculum materials that lead to changes in teaching and learning (Remillard, Lloyd, & Heiber-Eisenmann, 2009); (2) teachers’ implementation of the Common Core State Standards in Mathematics (CCSSM), standards for learning at each grade that recently have been adopted by almost all states in the U.S.; and (3) STEM-focused high schools as alternative settings for teaching and learning (NRC’s Committee on Highly Successful Schools or Programs in K-12 STEM Education, 2011).

Brown (2009) uses the term pedagogical design capacity to describe how teachers perceive, mobilize, and make decisions with curricular resources. We apply and extend this idea to explore the relationship between teachers’ planning and instructional practices and their recognition and uptake of resources in curriculum materials. Historically, U.S. teachers have drawn on curriculum materials with little consideration of how those materials provoke student reasoning or productive engagement in mathematical practices (Brown, Phelps, Otto, & Ketsi, 2009; Grouws, Smith, & Stache, 2004; Weiss, Barlouwer, McShan, & Smith, 2001), a trend exacerbated by states’ interpretations of the No Child Left Behind legislation, which has resulted in more narrow and scripted forms of curriculum and instruction (Darling-Hammond, 2010). This is particularly problematic because we know that teachers can use curriculum resources to impact student learning.

The simultaneous implementation of the CCSSM across virtually the entire nation presents great challenges to teachers and districts as they attempt to align their curriculum and instruction to address the new standards. The CCSSM do not stipulate specific curriculum resources, leaving open to teachers what resources to draw on and how to use those resources to design instruction. Past research suggests that teachers will face challenges in enacting the new standards and in using them to design instruction in ways that emphasize student reasoning (Brown et al., 2009; Conley et al., 2008; Remillard, 2005; Tarr et al., 2008).

Research exploring the link between STEM education programs and student learning outcomes is limited (Government Accountability Office, 2012). A recent report (NRC, 2011) highlights the need for research on STEM-focused schools that “identifies and describes distinctive aspects of high-leverage practices” (pg. 17). In fact, there are no explicit criteria for a STEM-focused school, and this is limited (Government Accountability Office, 2012). A recent report (NRC, 2011) highlights the need for research on STEM-focused schools that “identifies and describes distinctive aspects of high-leverage practices” (pg. 17). In fact, there are no explicit criteria for a STEM-focused school.

Context: The STEM-Focused High School, Students, and Teacher
A public high school with no minimum entrance requirements, based on an inclusive model (National Research Council, 2011), recruiting and retaining students from underrepresented groups in numbers proportional to district demographics – admission does not depend on students’ past achievement (i.e., not a “magnet school”).

• The curriculum includes an emphasis on:
  a) Standards-based mathematical (National Governors Association, 2010), science, and engineering practices (National Research Council, 2012)
  b) Project-based learning (PBL, Blumenfeld et al., 1993)
  c) Partnerships with STEM-related businesses and industries (students interacted weekly with mentors from STEM fields and experience internships and field trips off-campus)
  d) Cross-curricular integration
• The school opened in Fall 2009, admitting only 9th graders and adding a grade each year. The school population will be capped at 400 in Fall 2012, with grades 9-12. Enrollment currently includes approximately: 80 eleventh-graders; 90 tenth-graders and 95 ninth-graders.
• Students come from three public school districts with minority populations of 40.4%, 74.9%, and 28.0%, respectively, and free and reduced lunch eligibility of 47.9%, 71.8%, and 28.4%, respectively. STEM-school students reflected the demographics of their districts.
• The case study mathematics teacher taught 9th and 10th grade classes of mathematics.

Methods
A mixed-methods convergence model (Creswell & Clark, 2007) was employed to merge quantitative and qualitative information to produce conclusions and implications about contexts, phenomena, and outcomes.

• A qualitative, intrinsic case study (Stake, 1995) was used to explore the unique context of an innovative, STEM-focused high school and the nature of mathematics teaching and learning practices in this school.
• Quantitative measures were used to examine student outcomes in the form of state mathematics assessments and whether they were significantly different from students’ scores in their districts and state.

Data Sources
• To study the teacher’s practice during planning and instruction, data included: audio-recordings of planning sessions (with transcription), video-recordings of classroom observations (with transcription), artifact collection of curriculum resources.
• To examine effects of teaching practice on students’ learning, data included: students’ work samples and students’ scores on state mathematics assessments.

Data Analysis
• Classroom-based data were analyzed through open coding (Corbin & Strauss, 2008) and analytic induction (Bogdan & Biklin, 1992) to identify patterns of similarities/differences and emerging themes in the teacher’s planning and teaching practices and in students’ work.

Discussion and Implications
• The teacher implemented tasks that required higher level thinking by asking for explanations, justifications, and connections to other ideas and experiences (Smith & Stein, 2012). Focused on quality of thinking and reasoning rather than quantity of problem-solving.

Effects of a STEM-Focused School on Teaching and Learning
• Teachers and administrators throughout the school perceived curriculum materials as resources and that “teachers do not teach a textbook – teachers teach students” (expressed at staff meetings on several occasions).
• Teachers throughout the school enacted teaching practices that emphasize: working in groups; project-based learning; class discussions that focus on reasoning, justifying, and arguing (as compared to absorbing information); learning that connects to other disciplines, to everyday life, and to STEM professions.

Math Year 1 Exam Math Year 2 Exam

<table>
<thead>
<tr>
<th>District A</th>
<th>District B</th>
<th>District C</th>
<th>STEM School</th>
<th>State</th>
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<td>Math Year 1 Exam</td>
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Note: * p < 0.05.

For effect sizes (d), 0.2, 0.5, 0.8 represent small, medium, and large differences, respectively.

Discussion and Implications
• In many ways, this teacher and school serve as evidence that these approaches can influence students learning positively – both on state assessments and for deeper levels of learning and thinking.
• Attending to standards and drawing from multiple curriculum materials is highly complex and demanding work, requiring a deep understanding of mathematics content and pedagogy; considerable time and planning outside of the school day; and continual revision and adjustments during teaching. Are most teachers prepared to do this work? Can this kind of work be done at a large scale?

• A school-wide culture that enacts research-based teaching practices and upholds high expectations for students’ learning is critical. Teachers would face even greater challenges if they tried to implement these practices in isolated classrooms.

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