

Qualities of Effective Math Teachers

Rachel D. Kaboré

University of Nebraska - Omaha

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Abstract

Qualities of effective math teachers have been prioritized in the United States since international tests showed American students' math and science test scores falling below other students in developed countries. This research brief examines strategies of effective math teachers and how effectiveness is measured. Current research indicates that building both teacher and student self-efficacy has shown positive outcomes on student achievement and engagement in the classroom. Additionally, current research indicates that when teachers utilize certain strategies they can positively impact student success in mathematics.

Title

Qualities of Effective Math Teachers

Research Topic

This research brief explores the factors that distinguish highly effective teachers in the math classroom. Similarities and differences among elementary, secondary, and collegiate teachers are considered.

Introduction

Math Achievement Gaps in the United States

Student success in math is essential, as it is the foundation for many science, technology, and engineering jobs (Martin & Rimm-Kaufman, 2015). Math achievement may be associated with future economic power and competitiveness of a country thus making it desirable to find factors associated to positive relationships with mathematics achievement to countries around the world (Son, 2015). Improving student achievement in mathematics and science has been a concern in the United States (U.S.) since the early 1980s, when international tests began showing U.S. students falling behind most developed countries in mathematics and science skills which painted a less than glamorous picture of the quality of the American math and science teaching field (Gningue, Peach, & Schroder, 2013; Moyer-Packenham, Bolyard, Kitsantas, & Oh, 2008).

Teacher Effectiveness: Strategies and Measurements

Moyer-Packenham, et al. (2008) identified the most common teacher characteristics examined include teacher behaviors, practices and beliefs, subject and pedagogical knowledge, and certification. Surveys, questionnaires, and exams were most commonly used to assess math teacher quality. This study found while the U.S. has been motivated to hire highly qualified

teachers since the goal development of No Child Left Behind, there are few instruments available that effectively measure quality characteristics of mathematics teachers.

While teacher effectiveness is often times measured by student achievement on standardized assessments, Knight et al. (2015) states that this limits the qualities of effective teachers to the skills that can be measured by achievement tests. It is suggested that focusing on teacher inputs and standardized testing effects is a reflection of *teacher* quality; whereas, a focus on classroom practice is a reflection of *teaching* quality. It is therefore encouraged to define quality in terms of cognitive resources and performance, and to focus on *teaching* quality connected to student learning instead of teacher characteristics. Educators are encouraged to consider teacher affect when defining characteristics of effective teachers. Such teacher affects may include compassion, fairness and respect, interactions with students both in and out of the classroom, enthusiasm, motivation, attitudes toward teaching, and reflection.

Teacher effectiveness may also be considered in regards to student expectations in the classroom. Martin and Rimm-Kaufman (2015) emphasize that ideal math learning is not a passive process of memorizing and using standard algorithms, instead students engage in reasoning, problem solving, and discourse with teachers and other students to explore mathematical problems.

Summary of Findings

Characteristics of Teacher Quality in the Math Classroom

Through a review of literature on mathematics and science teacher quality, Bolyard and Moyer-Packenham (2008) identified six primary characteristics as indicators of teacher quality: general ability; experience; pedagogical knowledge; subject knowledge; certification status; and teacher behaviors, practices, and beliefs with a focus on student achievement as the dependent

variable. They found studies generally point to a positive relationship between teachers' general and verbal ability and student achievement in mathematics. The relationship between teaching experience and mathematics achievement provided mixed results; however, more studies found a positive relationship, especially at the secondary level (Moyer-Packenham et al., 2008).

When measuring qualities of effective math teachers by student engagement, it is helpful to understand what student engagement entails. For the purpose of their study, Martin and Rimm-Kaufman (2015) recognized emotional and social engagement. They describe emotional engagement as a student's enjoyment and interest in math, which they considered critically important to motivation and success. Social engagement includes positive exchanges between peers that connect to the instruction with an understanding that when students feel effective in math, they are more comfortable working with a group and helping others. Student engagement stems from internal processes and external supports including classroom experiences, and a student's sense of self-efficacy in math and supportive teacher-student interactions. Some of the ways teachers provide support include being caring and aware of student interests and needs, having clear expectations, providing explicit feedback, and creating opportunities for conceptual thinking (Martin & Rimm-Kaufman, 2015).

Qualities of Effective Teachers in Elementary Math

Elementary education majors have the highest levels of math anxiety of any college major (Hembree, 1990), and children are more likely to emulate the behavior and attitudes of same gender adults (Bussey & Bandura, 1984); therefore, when female elementary teachers are anxious about math, there are negative consequences for their female students. In their research on first and second grade teachers and students, Beilock, Gunderson, Ramirez, and Levine (2010) found that girls' math achievement is related to traditional gender ability beliefs; girls

who believed boys were better than girls at math were outperformed by girls who did not hold this viewpoint, and female teacher anxiety affects these beliefs. In these classrooms, the academic achievement of boys were not affected by the anxiety of their female teachers. While elementary math majors have high levels of math anxiety, Bolyard and Moyer (2008) found that at the elementary level, it is more beneficial for teachers to have degrees in education than mathematics; however, the study noted that it is rare to find elementary teachers with degrees in mathematics which may influence the data. It was also suggested that requiring teachers to study more math is only helpful if teachers are learning the math in ways that will help them better instruct their students in the area of mathematics.

In their study of fifth grade students, Martin and Rimm-Kaufman (2015) found students with higher levels of self-efficacy reported greater levels of engagement in math class, and students who were in classrooms with high levels of emotional support also reported similar levels of engagement, regardless of initial self-efficacy. Moreover, students at risk for problems in school due to low self-efficacy appeared to benefit more from high quality emotional support than those students without risk. Students high in self-efficacy are engaged regardless of teacher support; however, the engagement of students low in self-efficacy fluctuate based on teacher support (Martin & Rimm-Kaufman, 2015).

In a study regarding teachers' ability and help attributions in relation to children's math performance and task persistence amongst third graders in Estonia, Tõeväli and Kikas (2016) found that the more teachers attributed children's math success to teacher help or math failure to lack of ability, the poorer the children's math performance was. The task persistence of the students also had a positive effect on their math performance; the more persistence students demonstrated in second grade, the better their math performance was in third grade. In addition,

the stronger a student's math performance was in second grade, the more persistence showed later. The authors noted that boys showed lower levels of persistence than girls did in this study.

O'Donnell (2009) studied the work of elementary teachers who created and maintained instructional environments that promoted mathematical learning through problem solving. Through these studies, she found Carol. Carol's strategies include holding high expectations by not setting limits on what students were capable of learning; allowing students time to think through processes such as think-pair-share so they had both individual and group problem solving; giving students responsibility to discuss problems, pose possible strategies to solve problems, make connections between mathematical concepts, and present answers; and accepting the idea that some students will not get the answer because their reasoning is flawed. O'Donnell also met Brenda and Laurel who had similar strategies that include anticipating students' tension as anxiety leads students to focus on memorization and causes them to lose self-esteem which inhibits their abilities to learn the big ideas and concepts; and fostering quality interactions by using effective questioning techniques and making conscientious decisions about when and how to provide information.

Qualities of Effective Teachers in Secondary Math

Bolyard and Moyer (2008) found that at the secondary level, teachers who hold a degree in mathematics appears to have positive impacts on student achievement while there is little or even negative impact on student achievement for teachers to have education degrees without a mathematics degree. However, teacher coursework taken specifically in the area of mathematics has a positive relationship on student achievement; yet, this seems to be limited, as one study found the impact diminishes after a certain number of courses and is influenced by the level of course. Overall, teachers who have degrees in mathematics have positive impacts on student

achievement, and there is a positive relationship between subject-specific certifications and student achievement. While there is a positive relationship between mathematics courses and student achievement, Bolyard and Moyer, 2008, indicate that preparation in pedagogy is also important. Programs that compromise on subject matter training with teachers having a limited mathematical understanding of the content has detrimental effects on pedagogical content knowledge and negative effects on instructional quality and student progress which persist across their entire teaching careers (Baumert et. al, 2010).

The Mathematics Teacher Transformation Institute measured effectiveness of teaching by measuring student engagement in math; Gningue et al. (2013) found that teachers who employed a high level of student-centered, inquiry-based pedagogy were more effective algebra and geometry teachers than those who did not. However, they also found there was no relationship between the increase in content knowledge and a teacher's use of student-centered teaching. Son (2015) found in a study of eighth grade students in the United States and Korea that while teachers' educational backgrounds are not associated with high-quality mathematics instruction in Korea, the opposite is true in the United States where teachers who majored in both education and mathematics are 2.4 times more likely to be classified into the high quality group than teachers who did not major in education or mathematics and used an alternative path to the teaching profession. Professional development opportunities were a distinguishing factor for teachers who had high-quality instruction but low self-efficacy and for teachers who had low-quality instruction but high self-efficacy from those that were low in both quality instruction and self-efficacy. In the United States, there is a positive relationship between mathematical instruction, teacher self-efficacy, and student achievement in mathematics; however, in Korea, there is no significant relationship amongst the three. The discrepancy regarding the

effectiveness of teacher coursework or content knowledge can be explained by the process of measuring effectiveness; when evaluating student achievement there is a positive correlation; whereas, when evaluating student engagement there was no relationship.

While Bolyard and Moyer's (2008) research focused on teacher coursework, Judson (2017) focused on practices of math teachers in different courses including advanced placement (AP), honors, and regular classes. While he did not evaluate the effectiveness of teacher strategies on student outcomes, Judson (2017) did find significant differences in expectations. Math teachers who taught a combination of AP, honors and regular math classes indicated they believe students in AP classes should be assigned homework on a more regular basis and the lessons should have more explicit structure than in regular math courses. In their honors math courses, teachers felt it was better to go into more depth on fewer topics; whereas, in the AP courses, teachers did not hold this view and may have felt they were not allowed to omit any topics. In their AP classes, teachers indicated placing significantly greater emphasis on understanding mathematical ideas, emphasizing mathematical practices, understanding real-life application, increasing interest in math and preparing for further study in mathematics than in their regular math courses.

Compared to their honors classes, teachers indicated placing significantly greater emphasis on developing computation speed, understanding mathematical ideas, developing mathematical practices, and integrating real-life applications in their AP courses. While writing reflections was not reported as common in math courses, teachers did report that it occurred significantly more often in AP courses than regular courses. In general, AP courses were reported as being more student-centered and engaging than regular math courses where students

are less engaged with practices which promote critical thinking and reflection which Judson (2017) identifies as valuable practices that should occur in all levels of math.

In a study focused on secondary math teachers from Teach For America (TFA), an alternative route to teacher certification, Chiang, Clark and McConnell (2017) found that TFA teachers outperformed comparison teachers on both the Praxis II Mathematics Content Knowledge Test and the Praxis II Middle School Mathematics Test. The two-year study compared TFA teachers and teachers from other certification routes teaching the same math course, typically at the same class period. Fewer TFA teachers had majored in mathematics or secondary math education, but more TFA teachers had majored in other math-related subjects than the comparison teachers; 59% of the comparison teachers were from traditional education programs and 41% were from alternative certification programs other than TFA. Based on student scores on end-of-year math assessments, the researchers found TFA teachers to be more effective than comparison teachers teaching the same math courses in the same schools.

Our study provides experimental evidence from multiple school districts that TFA's distinctive model of recruiting, selecting, training, and supporting its teachers is capable of raising both the quantity and quality of teachers in a hard-to-staff subject area within high-poverty schools. (Chiang et al., 2017, p. 35)

While students were not brought up to the mean of the general population on their end-of-year math assessments, the gap was narrowed.

While O'Donnell (2009) primarily studied elementary teachers with effective math strategies, she did gain some insight from Belinda, a middle grades teacher. Belinda's lesson strategies include researching each problem by dissecting the mathematical concept, determining potential strategies students may use, and preparing connections to other mathematical concepts;

using challenging problems to extend student reasoning and build mathematical understanding; and not giving up on students or on self by recognizing students learn from their mistakes and she can learn from her shortcomings.

Urduan and Schoenfelder (2006) identified teaching strategies that lead to academic success in the classroom such as emphasizing students' efforts in learning, helping students make connections between tasks, modeling strategies, and scaffolding that allows students to take risks.

Qualities of Ineffective Teachers in College Courses

A study was conducted to gain knowledge on not-so-good instructors at the collegiate level. The researchers found that poor teaching is not necessarily the inverse of good teaching but is based on key reciprocals including being disrespectful, offering unrepresentative and unfair student learning assessments, having unrealistic expectations for student learning, and being less than knowledgeable on course content. They recommended that all teachers, not just college and university teachers, should avoid these qualities (Busler, Kirk, Keeley, & Buskist, 2017).

Summary of the Characteristics of Effective Teachers and Student Self-Efficacy

Student success in the area of mathematics is influenced by both the teacher and the student. Qualities of effective math teachers that build student self-efficacy and encourage success in the math classroom in the U.S. include providing emotional support, believing students can be successful in math regardless of gender, attributing student success to the student, maintaining high expectations in a student-centered, inquiry-based classroom, and having solid content knowledge.

Implication of the Findings and Application to MOEC

Implication of the Findings

In their study of Slovene eighth grade students, Puklek Levpušček and Zupančič (2009) found parental academic pressure appeared to be the strongest predictor of mastery goal orientation, academic self-efficacy, and achievement in math; the counterproductive effect of student-rated parental academic pressure was demonstrated through the negative effect on students' self-efficacy in math and that parental academic pressure and support were negatively related to students' math grades. On the other hand, there was a positive relationship between math teaching and student self-efficacy, mastery goal orientation, and achievement in the math domain. Their study also revealed that students' self-efficacy in math significantly contributes to their final math grade. Puklek Levpušček and Zupančič (2009) realize a combined effect of both student-rated family and classroom context on eighth grade math performance is stronger than the effect of either one alone. They also found teachers' classroom behaviors predominantly contributed to students' grades by building students' self-efficacy in math; therefore, focusing professional development on instructional practices and communication skills that build self-efficacy should be considered when striving to improve student achievement in the area of mathematics.

Both preservice and inservice professional development seems to be a powerful tool in improving the quality of teaching and raising student achievement. Math anxiety of elementary teachers can be reduced through math training and education (Gresham, 2007). In the United States, to improve student achievement in mathematics, there must be a focus on cognitively demanding instruction and teacher self-efficacy (Son, 2015). With a focus on tying classroom

practice to student learning, preservice and inservice professional development aligned to increasing quality of teaching and learning is imperative (Knight et al., 2015). Knight et al. (2015) further explains that quality teaching will depend on teachers who enter the profession with a solid foundation and build on that foundation throughout their careers which includes the ability to assess student knowledge and content needs and effectively respond to those needs, a commitment to lifelong learning through professional development. These teachers must also value the individual and sociocultural knowledge of diverse learners and know how to connect and built on that knowledge.

When students feel challenged in math, effective teachers help students understand that although the work seems hard, they are capable of meeting the high expectations. Student self-efficacy in math can be enhanced by promoting a growth mindset rather than a fixed mindset sending the message that with effort, ability can be developed. Building teacher-student relationships is one way to improve emotional and social engagement (Martin & Rimm-Kaufman, 2015).

If the mathematical success of children is attributed to help from teachers, children may feel they have little control over their performance; therefore lowering overall performance. The reactions of teachers and their casual attributions may affect children's learning and motivation; therefore teachers should be aware of the message they are sending students through comments, feedback, praise, etcetera (Tõeväli & Kikas, 2016).

Application to Metropolitan Omaha Educational Consortium (MOEC)

The MOEC Achievement Plan Strategic Framework indicates a strategic priority to focus on increasing the number of highly qualified educational professionals with a focus on high need areas. MOEC's shared metrics include students meeting academic proficiency in reading and

mathematics, hiring highly qualified professionals having certification and degrees in high need areas, and graduating students from high school who are prepared for postsecondary and career success (MOEC, 2018). MOEC is comprised of twelve public school districts, two educational service units, a metropolitan university, and two community colleges; because MOEC serves a large portion of educators in the metropolitan area, it would be beneficial for this consortium to plan both preservice and inservice professional development opportunities to build self-efficacy of elementary math teachers and to guide instructional practices to enhance student self-efficacy. It would also be worthwhile to have discussions amongst the school districts to evaluate expectations in all math classes and how they relate to students' academic outcomes. Professional development in the area of student-centered inquiry-based classrooms would also be beneficial, as studies have found positive correlations to student achievement and engagement.

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Author's Information

Rachel Kaboré is a doctoral student at the University of Nebraska at Omaha. Prior to her doctoral work, Rachel earned her master's degree in Educational Leadership from Doane College and her bachelor's degree in Education from the University of Nebraska at Lincoln. Rachel is currently a curriculum coordinator for the Elkhorn Public Schools. In her role as curriculum coordinator, Rachel works with teachers on district common assessments, manages online textbooks, and provides professional development. Prior to her work as a curriculum coordinator, Rachel taught middle school reading, language arts, and math for the Elkhorn Public Schools and was a member of the school improvement team and the student assistance team leader. Rachel values providing opportunities for students that open doors to their futures.