A CHARACTERIZATION OF TEACHERS' IMPLEMENTATIONS OF A MATHEMATICAL DECISION-MAKING CURRICULUM

Krista Holstein
North Carolina State University
kaholste@ncsu.edu

Karen Allen Keene
North Carolina State University
kakeene@ncsu.edu

*The purpose of this study was to examine teachers' implementation of a specific mathematics curriculum and how their conceptions influenced this implementation. An innovative, powerful tool, known as "teacher logs," was used to examine teachers' implementations of the curriculum; a survey was used to study teachers' conceptions related to their implementations. Results suggest that teachers tend to implement the materials closely to the written text, but there was variety shown both within and among teachers. A relationship was shown between teachers' implementation levels and **their** beliefs about mathematics and their beliefs about students. The results of this study reveal that teachers may or may not stray from the authors' intended curriculum, and whether or not they stray often relates to their conceptions.*

Keywords: Curriculum, Curriculum Analysis, Teacher Beliefs

When new curricula are developed, researchers, policy makers, and teachers often ask, "Do these materials work? Are these materials effective?" As a result, a committee was charged by the National Research Council (NRC) to determine the quality of curriculum evaluations. In their report, *On Evaluating Curricular Effectiveness* (NRC, 2004), the committee defined curricular effectiveness as, "how effective a particular curriculum is, and for whom and under what conditions it is effective" (p. 1). When determining curricular effectiveness, one important part to consider is teachers' faithfulness to the curriculum authors' intentions because if teachers do not implement the materials as the authors intended, they may undermine the effectiveness of the new curriculum. Specifically, implementation fidelity needs to be considered. Holstein, Dietz, and Keene (2010) defined implementation fidelity as "the extent to which a teacher implements a curriculum as the author intended, allowing for adaptation, supplementation, and improvisation by the teacher" (p. 2). The concept of implementation fidelity is not equivalent to teacher quality. That is, low implementation fidelity does not suggest poor teaching. Rather, researchers study implementation fidelity to determine the extent to which the teacher implemented the materials. This information can then be used, in part, to determine curricular effectiveness.

Recent research on implementation fidelity has emerged partly because teachers often transform the written curriculum into a form completely different from the authors' original intentions. One may ask, "Why does this transformation occur?" One explanation is teachers' conceptions (e.g., about math, teaching, students, or curricula) influence their instructional decisions. Therefore, when examining implementation fidelity, it is important to consider teachers' conceptions. We use the word "conception" in the way Lloyd and Wilson (1998) used it: "to refer to a person's general mental structures that encompass knowledge, beliefs, understandings, preferences, and views" (p. 249)

Context and Purpose of the Study

The context for this study is the NSF-funded Mathematics for Decision-Making (MDM) curriculum (Project DRL-0733137). The emphasis of this curriculum is on decision-making using mathematical models based on engineering concepts. The text contains large real-world

Martinez, M. & Castro Superfine, A (Eds.). (2013). *Proceedings of the 35th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* Chicago, IL: University of Illinois at Chicago.

problem contexts that require multiple steps to solve and interpretation of the solution. The curriculum is intended for high school seniors who have completed two years of algebra and one year of geometry (or the equivalent).

The purpose of this study was to examine teachers' implementations of the MDM curriculum and how their conceptions influence their implementations. In particular, we studied how closely teachers' enacted curriculum aligned with the authors' intended curriculum. We also investigated teachers' conceptions that could bring their enacted curriculum closer or farther from the authors' intended curriculum. The particular conceptions we considered were teachers' (a) subject matter knowledge, (b) beliefs about mathematics, (c) beliefs about students, (d) beliefs about teaching, and (e) beliefs about curricular materials.

The research questions were as follows:

1. How do teachers' implementations of a mathematical decision-making curriculum align with the authors' intentions?
2. How do teachers' conceptions influence their implementations of a mathematical decision-making curriculum?

Research Background

The NRC (2004) developed a framework to define "what is meant by a scientifically valid evaluation study for reviewing mathematics curriculum effectiveness" (p. 36). It included three major components for curriculum evaluations: "(1) the program materials and design principles; (2) the quality, extent, and means of curricular implementation; and (3) the quality, breadth, type, and distribution of outcomes of student learning over time" (p. 4). Scientifically valid evaluation studies on curricular effectiveness should include all the components of this framework. In the present study, we examined the "Implementation Components" (the second major component) piece of the framework, with the understanding that future studies should include the other components of the framework to determine the overall effectiveness of the MDM curriculum.

One way to study the implementation components of a curriculum is to examine how the curriculum transforms from the written materials to what students actually experience in the classroom. Stein, Remillard, and Smith (2007) provided a framework for studying the transitions of the curriculum from its written form to its enacted form, as shown in Figure 1.

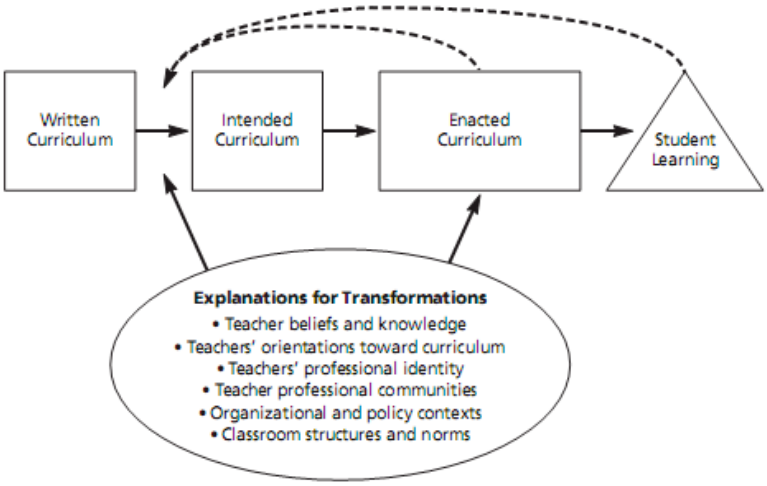

Figure 1: Temporal Phases of Curriculum Use (Stein et al., 2007, p. 322)

The curriculum begins as a written curriculum, which refers to the authors' original printed materials. Then, the curriculum changes into what the teacher intends to teach. This initial transformation occurs due to teachers' conceptions, goals, and contexts, as shown in the oval in Figure 1. Next, the curriculum transforms again into the enacted curriculum, which is the classroom implementation of curriculum materials. The enacted curriculum is also influenced by outside factors. Finally, student learning occurs. Therefore, it is unreasonable to measure the connection between the written curriculum and student achievement without considering the transformations of the curriculum. In other words, to determine whether a curriculum is effective, one must study whether the teacher is using the curriculum as intended by the curriculum authors.

To capture the implementation and to connect it to the authors' intentions, Heck, Chval, Weiss, and Ziebarth (2012) created two constructs: (a) the *mathematical storyline*, which refers to "which topics are addressed, at what depth different topics are addressed, and/or what learning goals and student expectations are pursued" (p. 69) and (b) the *pedagogical storyline*, which includes "which activities are conducted and how they are conducted in terms of openness or guidance, how students are grouped for instructional activities, and whether the patterns of interaction that are designed are actually pursued" (p. 70). These two constructs guided the methodology of this study (described below).

Moreover, one reason the transformation from written curriculum to enacted curriculum occurs is teachers' conceptions. Many conceptions influence teachers' instructional decisions and thus their implementation fidelity. Five conceptions which consistently emerged in the literature as influencing teachers' instructional decisions were examined in this study: (a) subject matter knowledge (e.g., Manouchehri & Goodman, 1998), (b) beliefs about math (e.g., Collopy, 2003), (c) beliefs about teaching (e.g., Stipek, Givvin, Salmon, & MacGyvers, 2001), (d) beliefs about students (e.g., Arbaugh, Lannin, Jones, & Park-Rogers, 2006), and (e) beliefs about curricular materials (e.g., Frykholm, 2004).

Methodology

In this paper, we present the quantitative portion of a mixed-methods study (see Holstein, 2012). To answer the first research question, an innovative tool called "teacher logs" was used. To answer the second research question, a survey was used, where the survey results were compared to the teacher log results. The participants came from the population of high school mathematics teachers who attended an MDM workshop ($N = 232$). Thirteen teachers completed at least one teacher log; 12 teachers completed the survey *and* at least one teacher log.

Teacher Logs

Huntley (2009) stated, "If we truly want to understand the relationships among textbooks, teaching, and student learning, it is critically important to develop curriculum-sensitive measures of implementation" (p. 357). In this study, we used teacher logs (Heck et al., 2012) as our "curriculum-sensitive measures of implementation." Teacher logs were developed by the first author of this paper for five chapters in the MDM curriculum (one teacher log per problem context and approximately three problem contexts per chapter, for a total of 16 logs). Each log contained a list of items for teachers to choose from, where each item illustrated an instructional choice. Every effort was made to include all possible implementation choices. Teachers checked off items that they did during their implementation of the curriculum, where each item (a) supported the authors' intentions, (b) went against the authors' intentions, or (c) was neutral. For example, the MDM curriculum authors included several in-text questions for students to answer themselves, either individually, in groups, or as a class. Therefore, the following item went

Martinez, M. & Castro Superfine, A (Eds.). (2013). *Proceedings of the 35th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* Chicago, IL: University of Illinois at Chicago.

against the MDM authors' intentions: "I led a class discussion that covered the information out of in-text questions #1-2 (but did not explicitly ask these questions)." On the other hand, the following item supported the authors' intentions: "Students read and answered in-text questions #1-2 out loud or individually."

Teachers received four scores for each log: (a) a mathematical adherence score, (b) a mathematical focus score, (c) a pedagogical adherence score, and (d) a pedagogical focus score. The two mathematical scores were based on items that either supported or went against the curriculum authors' mathematical storyline; the two pedagogical scores were based on items that either supported or went against the curriculum authors' pedagogical storyline.

The mathematical and pedagogical *adherence* scores refer to how the teacher supported the authors' intentions. These scores were calculated using the following ratio, which yielded a score between 0 and 1:

$$\frac{\text{Number of fidelity elements enacted}}{\text{Total number of fidelity elements}}$$

A high mathematical adherence score means that the teacher addressed most of the content of the curriculum, while a low mathematical adherence score means that the teacher addressed little of the content of the curriculum. A high pedagogical adherence score means that the teacher addressed most of the instructional strategies of the curriculum, while a low pedagogical adherence score means that the teacher addressed little of the instructional strategies.

The mathematical and pedagogical *focus* scores took into account the fidelity elements as well as the items that went against the authors' intentions. These scores were calculated using the following ratio, which yielded a score between 0 and 1:

$$\frac{1 + \frac{\text{Number of fidelity elements enacted}}{\text{Total number of fidelity elements}} - \frac{\text{Number of other elements enacted}}{\text{Total number of other elements}}}{2}$$

A high mathematical focus score means that the teacher addressed more of the content of the MDM curriculum than other content, while a low mathematical focus score means that the teacher addressed less of the content of the MDM curriculum than other content. A high pedagogical focus score means that the teacher addressed more of the instructional strategies of the MDM curriculum than other instructional strategies, while a low pedagogical focus score means that the teacher addressed less of the instructional strategies of the MDM curriculum than other instructional strategies. Notice that the adherence score is one piece of the focus score.

Each teacher's mathematical adherence, mathematical focus, pedagogical adherence, and pedagogical focus scores were averaged. In the end, each teacher had four scores, regardless of how many logs they completed. These scores informed us about teachers' levels of implementation fidelity.

Survey

The purpose of the survey was to gather data on teachers' conceptions. The survey items were adapted from previously validated surveys, where each item measured one of the five conceptions included in this study: (a) beliefs about curriculum (items adapted from Spielman & Lloyd, 2004), (b) beliefs about math (items adapted from Fennema & Sherman, 1976; Perry, Howard, & Tracey, 1999; Suinn, 1988), (c) beliefs about teaching (items adapted from Perry et al., 1999; Spielman & Lloyd, 2004), (d) beliefs about students (items adapted from Fennema & Sherman, 1976; Suinn, 1988), and (e) subject matter knowledge (items heavily adapted from McDiarmid & Wilson, 1991). Note that the "beliefs about curriculum" survey items asked teachers about their beliefs about general curricula and were not specific to the MDM

curriculum; the "beliefs about math" survey items portrayed mathematics on a traditional to nontraditional continuum (Raymond, 1997). All items were on a five-point Likert scale, with the exception of the subject matter knowledge items, which were multiple choice.

Teachers received five scores on the survey (one for each conception). Then, a Spearman's Rank Order correlation was conducted to determine any correlations between the five survey scores and the four teacher log scores.

Results

In this section, we present the results for the two research questions. First, the teacher log results show teachers' implementation fidelity levels during their implementations of the MDM curriculum. Second, the correlations between the teacher log results and the survey results are offered to illustrate teachers' implementation fidelity levels related to their conceptions.

Implementation Fidelity

Averages for the four teacher log scores were calculated for each of the 13 teachers, regardless of the number of logs completed. Table 1 shows the overall results from these logs. In this table, the average score and standard deviation are given for each teacher for each of the four scores. This table also gives the following overall data: (a) the average of the teacher averages, found by averaging the average scores for the 13 teachers; (b) the standard deviation of the teacher averages, found by calculating the standard deviation of the average scores for the 13 teachers; (c) the minimum teacher average score; and (d) the maximum teacher average score.

Table 1: Teacher Log Results

Teacher Number	Number of Completed Logs	Math Adherence		Math Focus		Pedagogical Adherence		Pedagogical Focus	
		Score	SD	Score	SD	Score	SD	Score	SD
T1	12	0.5822	(.1529)	0.7179	(.1238)	0.5451	(.2428)	0.6867	(.1640)
T2	7	0.6638	(.1933)	0.8149	(.0999)	0.7794	(.1969)	0.8897	(.0985)
T3	4	0.7572	(.1478)	0.7328	(.0898)	0.8333	(.2357)	0.8479	(.0851)
T4	1	0.9375	(--)	0.9688	(--)	0.8333	(--)	0.9167	(--)
T5	4	0.9480	(.0392)	0.8832	(.1078)	0.8294	(.2243)	0.8678	(.0884)
T6	1	0.8889	(--)	0.9444	(--)	1	(--)	1	(--)
T7	8	0.7284	(.1466)	0.7749	(.1398)	0.6217	(.2033)	0.6949	(.1829)
T8	7	0.7215	(.1609)	0.7307	(.1434)	0.6643	(.3473)	0.7388	(.2407)
T9	2	0.5729	(.3388)	0.7388	(.2368)	0.5	(.2357)	0.6688	(.0913)
T10	1	0.9444	(--)	0.7103	(--)	0.8889	(--)	0.9444	(--)
T11	4	0.8547	(.1219)	0.8023	(.0916)	0.9069	(.1114)	0.8991	(.0837)
T12	2	0.9444	(.0786)	0.7961	(.1116)	1	(0)	1	(0)
T13	1	0.9444	(--)	0.6627	(--)	0.5556	(--)	0.7465	(--)
Average of Teacher Averages		0.8068		0.7906		0.7660		0.8386	
SD of Teacher Averages		0.1427		0.0925		0.1714		0.1182	
Minimum		0.5729		0.6627		0.5		0.6688	
Maximum		0.9480		0.9688		1		1	

To help make sense of these data, consider two teachers in Table 1 (recall that all scores were between 0 and 1). First, T1 adhered to only about half of the mathematical and pedagogical

intentions (mathematical adherence score of 0.5822 and pedagogical adherence score of 0.5451), but this teacher tended to use the MDM content and instructional strategies more than *other* content or instructional strategies (mathematical focus score of 0.7179 and pedagogical focus score of 0.6867). Second, T3 had relatively high scores, but the pedagogical scores (0.8333 and 0.8479) were higher than the mathematical scores (0.7572 and 0.7328). Thus, this teacher tended to be slightly less faithful mathematically than pedagogically.

When looking at the overall averages, the pedagogical adherence had the lowest average (0.766); this means that teachers did not necessarily use the instructional strategies intended by the authors and that they only used approximately three quarters of the instructional strategies presented on the teacher logs. However, the pedagogical focus score had the highest average (0.8386); thus, teachers used *other* instructional strategies less than they used the strategies intended by the MDM curriculum authors. The individual teachers' standard deviation values show variety within teachers; the overall minimum, maximum, and standard deviation values show that there was variety among teachers.

Conceptions Related to Teachers' Implementation Fidelity

Each teacher received a score for each construct based on the five conceptions (beliefs about curriculum, beliefs about math, beliefs about teaching, beliefs about students, and subject matter knowledge). From these data, a Spearman's Rank Order correlation was conducted to examine correlations between the teachers' implementation fidelity scores on the teacher logs and their conception scores on the survey. Table 2 shows the results from this analysis, including the correlation coefficients and the p-values (in parentheses).

Table 2: Correlations between Implementation Fidelity and Conceptions

	Beliefs about Curriculum	**Beliefs about Math**	**Beliefs about Teaching**	**Beliefs about Students**	**Subject Matter Knowledge**
Mathematical Adherence	.194 (.545)	.629** (.028)	.072 (.824)	.127 (.694)	.051 (.875)
Mathematical Focus	.111 (.730)	.004 (.991)	-.046 (.888)	.077 (.811)	-.462 (.130)
Pedagogical Adherence	.301 (.342)	.327 (.299)	-.231 (.471)	.659** (.020)	-.268 (.399)
Pedagogical Focus	.426 (.167)	.357 (.255)	.054 (.866)	.536* (.072)	-.317 (.315)

*$p < .1$. **$p < .05$.

The test revealed that there was a statistically significant correlation ($p < .1$) between mathematical adherence and beliefs about math, between pedagogical adherence and beliefs about students, and between pedagogical focus and beliefs about students. All other relationships were not significant.

The results for each conception are discussed here. First, there were no significant correlations between teachers' beliefs about general curricula and their teacher log scores. Second, teachers' beliefs about math were significantly positively correlated only with their mathematical adherence scores. That is, teachers with more nontraditional views of math tended to adhere to the authors' mathematical storyline. Third, teachers' beliefs about students were significantly positively correlated with their pedagogical adherence and focus scores. That is,

teachers with positive views of students and their abilities tended to enact most of the instructional strategies of the MDM curriculum (high pedagogical adherence score) and to enact more of the instructional strategies of the MDM curriculum than *other* strategies (high pedagogical focus score). Fourth, there were no significant correlations between teachers' beliefs about teaching on the survey and their teacher log scores. Fifth, there were no significant correlations between teachers' subject matter knowledge on the survey and their teacher log scores, but lack of subject matter knowledge was nearly negatively correlated with teachers' mathematical focus scores ($p = .13$). This means that teachers who lacked subject matter knowledge sometimes used the MDM content more than other content.

Conclusion

To examine teachers' implementation fidelity to the MDM curriculum, a new tool, teacher logs, were used. These results showed that teachers were generally faithful to the authors' mathematical and pedagogical storylines. This is not surprising as these teachers volunteered to implement the MDM curriculum and to take part in the study. However, there was variety shown both within and among the teachers. These results support previous research on implementation fidelity (e.g., Crawford, Carpenter, Wilson, Schmeister, & McDonald, 2012; Remillard & Bryans, 2004; Stein & Kaufman, 2010), and we extended this research by showing results in the context of the MDM curriculum.

To investigate the connection between teachers' conceptions and their implementation fidelity of the MDM curriculum, a survey was used, where the survey results were compared to the teacher log results. These results showed that teachers' beliefs about math were significantly positively correlated with their mathematical adherence; thus, teachers with nontraditional views of math tended to implement the content of the MDM curriculum—a nontraditional curriculum—with high fidelity. According to previous research, how teachers view the nature of mathematics, its origins, and its usefulness influence their curricular decisions (e.g., Collopy, 2003). Stein et al. (2007) explained that sometimes curricular materials "offer views of mathematics that conflict with those typically held in mainstream culture" (p. 353). Thus, teachers may stray from the written curriculum if the goals do not align with their beliefs about math. The results of this study confirmed that if the goals align, adherence is stronger.

In addition, the results showed that teachers' beliefs about students were significantly positively correlated with their pedagogical adherence and pedagogical focus scores; that is, teachers with positive beliefs about students and their abilities tended to support and to not go against the authors' pedagogical storyline. Alternatively, teachers with negative beliefs about students and their abilities tended to have lower pedagogical adherence and focus scores. Past researchers showed how teachers' beliefs about students play a role in their instructional decisions (e.g., Arbaugh et al., 2006; Remillard & Bryans, 2004). In particular, Arbaugh et al. (2006) found results similar to those in the present study, where teachers with negative beliefs about students and their abilities often strayed from the authors' intentions. However, many teachers in their study with such beliefs strayed from the intended *content* while the MDM teachers primarily strayed from the intended *instructional strategies*. Thus, the results from the present study complement and add to the research connecting teachers' beliefs about students to their implementation fidelity.

The results of this study have implications for many. For example, curriculum developers need to be clear about intentions and provide support for teachers. Teacher professional developers need to be aware of how teachers implement curricula and the conceptions that influence their implementations. Finally, future researchers should utilize the new, innovative

Martinez, M. & Castro Superfine, A (Eds.). (2013). *Proceedings of the 35th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* Chicago, IL: University of Illinois at Chicago.

tool from this study: teacher logs. This tool is a powerful way to quantitatively study implementation fidelity.

References

Arbaugh, F., Lannin, J., Jones, D., & Park-Rogers, M. (2006). Examining instructional practices in Core-Plus lessons: Implications for professional development. *Journal of Mathematics Teacher Education*, *9*(6), 517–550.

Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. *Elementary School Journal*, *103*(3), 287–311.

Crawford, L., Carpenter, D. M., Wilson, M. T., Schmeister, M., & McDonald, M. (2012). Testing the relationship between fidelity of implementation and student outcomes in math. *Assessment for Effective Intervention*.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitude scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *JSAS Catalog of selected documents in psychology*, *6*(31).

Frykholm, J. (2004). Teachers' tolerance for discomfort: Implications for curricular reform in mathematics. *Journal of Curriculum & Supervision*, *19*(2), 125–149.

Heck, D. J., Chval, K. B., Weiss, I. R., & Ziebarth, S. W. (2012). Developing measures of fidelity of implementation for mathematics curriculum materials enactment. In D. J. Heck, K. B. Chval, I. R. Weiss, & S. W. Ziebarth (Eds.), *Approaches to Studying the Enacted Mathematics Curriculum*. Charlotte, NC: Information Age Publishing.

Holstein, K. A., Dietz, R. C. R., & Keene, K. A. (2010). The implementation of a decision-making curriculum. *Optimizing Student Understanding in Mathematics*. Paper presented at the 32nd Annual Conference of North American Chapter of the International Group for the Psychology of Mathematics Education, Columbus, OH.

Holstein, K. A. (2012). *A characterization of teachers' implementations of a mathematical decision-making curriculum* (Doctoral Dissertation). North Carolina State University, Raleigh, NC.

Huntley, M. A. (2009). Measuring curriculum implementation. *Journal for Research in Mathematics Education*, *40*(4), 355–362.

Lloyd, G. M., & Wilson, M. (1998). Supporting innovation: The impact of a teacher's conceptions of functions on his implementation of a reform curriculum. *Journal for Research in Mathematics Education*, *29*(3), 248–274.

Manouchehri, A., & Goodman, T. (1998). Mathematics curriculum reform and teachers: Understanding the connections. *The Journal of Educational Research*, *92*(1), 27–41.

McDiarmid, G. W., & Wilson, S. M. (1991). An exploration of the subject matter knowledge of alternate route teachers: Can we assume they know their subject? *Journal of Teacher Education*, *42*(2), 93–103.

National Research Council. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations*. Washington, D.C.: The National Academies Press.

Perry, B., Howard, P., & Tracey, D. (1999). Head mathematics teachers' beliefs about the learning and teaching of mathematics. *Mathematics Education Research Journal*, *11*(1), 39–53.

Raymond, A. M. (1997). Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for Research in Mathematics Education*, *28*(5), 550–576.

Remillard, J. T., & Bryans, M. B. (2004). Teachers' orientations toward mathematics curriculum materials: Implications for teacher learning. *Journal for Research in Mathematics Education*, *35*(5), 352–388.

Spielman, L. J., & Lloyd, G. M. (2004). The impact of enacted mathematics curriculum models on prospective elementary teachers' course perceptions and beliefs. *School Science and Mathematics*, *104*(1), 32–44.

Stein, M. K., & Kaufman, J. H. (2010). Selecting and supporting the use of mathematics curricula at scale. *American Educational Research Journal*, *47*(3), 663–693.

Stein, M., Remillard, J., & Smith, M. (2007). How curriculum influences student learning. In F. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (Vol. 1, pp. 319–369). Charlotte, NC: Information Age Publishing.

Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and Teacher Education*, *17*(2), 213–226.

Suinn, R. M. (1988). *Mathematics anxiety rating scale*. Fort Collins, CO: RMBSI, Inc.