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The Impact of Enacted Curriculum on Student Learning in Mathematics Classrooms[1)]

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The purpose of this study is to explore how elementary mathematics teachers' adaptations of a reform-oriented mathematics curriculum material in the USA, *Everyday Mathematics*, influence elementary students' opportunities to learn mathematics. I illustrate how elementary mathematics teachers alter the curriculum material and how such alterations influence their students' opportunities to learn mathematics in their mathematics classrooms. Results suggest that the teachers with *Everyday Mathematics* did not appear to maintain the cognitive demand of mathematical tasks as appeared in the curriculum material, as set up by the teacher, and as enacted in the classrooms. The results also show that the teachers seemed to omit components including important tasks and suggestions in the curriculum material. As a consequence, the students did not have an opportunity to think and understand mathematics conceptually and meaningfully; they were exposed and encouraged to learn mathematics procedurally.

Key Words: mathematics curriculum, student learning opportunities, enacted curriculum, teacher implementation, elementary grades

I. Introduction

Curriculum material is a critical medium with which teachers implement the content in classrooms. Mathematics curriculum materials guide what to teach among the various mathematical topics and ideas in mathematics classrooms and when is appropriate to teach them. The curriculum materials contain mathematical contents to teach in specific grade levels. In general, mathematics curriculum materials provide objectives of teaching specific mathematical contents and guidelines of how to teach for teachers. In particular, reform-oriented mathematics curriculum materials developed to

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support and implement the *Standards* suggested by National Council of Teachers of Mathematics [NCTM] (1989, 1991, 2000) provide teachers with more information on how to teach certain mathematical ideas conceptually. The NCTM *Standards* emphasize mathematics teaching for students' conceptual understanding through problem solving, reasoning for mathematical justifications, and mathematical communication and representation. This requires teachers have more and deep level of various knowledge and experiences (Stein & Kim, 2009).

Curriculum materials are viewed as a key vehicle to implement reform ideas in mathematics education on a large scale. That is, reform-oriented curriculum materials may contribute to change practices in mathematics classrooms, which would influence what and how students learn in their mathematics classrooms. With reform-oriented curriculum materials, mathematics teachers read and interpret the curriculum materials to plan their lessons. Then the teachers select and reorganize the contents and suggestions in the materials for their mathematics instruction. In doing so, they sometimes follow the guidelines suggested in the curriculum materials closely and often times modify the suggestions according to their students' mathematical capabilities (Kim, 2011). Such teachers' adaptations would influence students' learning in ways that limit or open wide students' opportunities to learn mathematics (Stein, Remillard & Smith, 2007). This study attempts to explore the relationships of mathematics teachers' adaptations of reform-oriented mathematics curriculum materials and students' opportunities to learn mathematics in elementary mathematics classrooms. Not many studies have investigated how mathematics teachers alter reform-oriented curriculum materials and thus, how such alterations influence students' opportunities to learn mathematics in most grade levels. Hence, this study would contribute to better understanding of the impacts of teachers' adaptations on students' mathematical learning in deeper level than by looking at content/topic coverage.

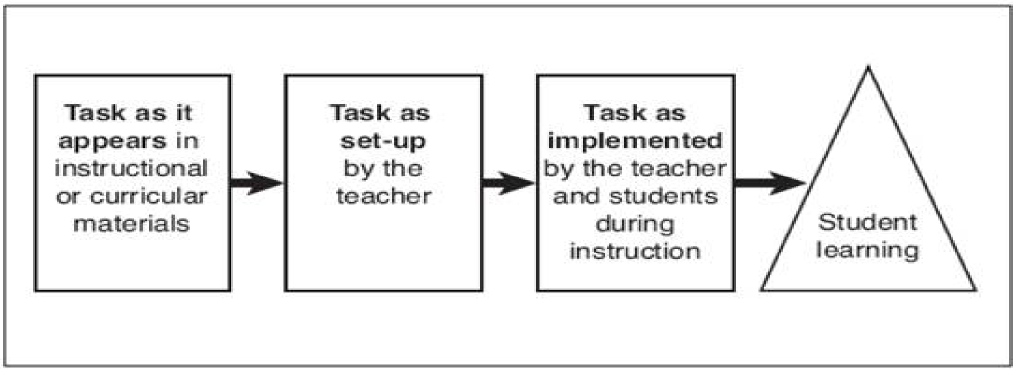
II. Conceptual Framework

Curriculum materials are tools to mediate mathematics teaching involving teachers and students. Teachers' learning should be supported through reform-oriented mathematics curriculum materials in order to implement reform through such materials in mathematics classrooms. Recent research studies reveal that curriculum materials must support and address teacher learning and student learning as well (Ball & Cohen, 1996; Davis & Krajcik, 2005). In particular, Collopy (2003) shows that teachers' learning can occur through the use of a reform-oriented curriculum material. Moreover, there are variations in reform-oriented mathematics curriculum materials in terms of teacher learning demand and support for teacher learning (Stein & Kim, 2009).

Teachers select instructional tasks and resources suggested in curriculum materials, which involves teachers' interpretations in their use of the materials (Ball & Cohen, 1996; Remillard, 1999, 2005). In other words, teachers read curriculum materials differently according to their individual needs and reasons (Remillard, 2000). This process leads teachers to adapt curriculum materials and such adaptation is a fundamental process with curriculum materials (Ben-Peretz, 1990). In particular, not only does teachers' early experiences with mathematics influence the ways teachers adapt curriculum materials, but also teachers' conceptions and interpretations of their recent experiences as adult learners of mathematics affect to adapt curriculum materials (Drake & Sherin, 2006).

Even with the same curriculum materials, enacted curricula by teacher and students look very different and thus, students experience different mathematical learning opportunities (Kilpatrick, 2003). For example, middle school students experience various degrees of mathematics in terms of mathematical content and topics and time spent on the content and topics, as a result of their mathematics teachers' decisions on what to teach (Tarr, Chavez, R. Reys, & B. Reys, 2006). In addition, elementary teachers use reform-oriented mathematics curriculum materials differently; teachers using *Everyday Mathematics* tend to modify the curriculum material by skipping or omitting activities and partially taking suggestions, rather than closely following the material (Kim, 2011); teachers lower the cognitive demands of tasks by breaking it down into smaller subtasks and by focusing on procedures (Henningsen & Stein, 1997; Smith, 2000).

Henningsen and Stein (1997) suggest the Mathematical Tasks Framework (MTF) (Figure 1) consisting of: a) task as it appears in curriculum materials; b) task as it is set up in the classroom; c) task as it is implemented in the classroom; and d) student learning. This framework describes the various phases that an instructional task can go through; first as it appears on the pages of a written curriculum, then as the teacher announces or sets it up in the classroom, and finally, as it is actually enacted in the classroom by the teacher and students. Often, the features of the task, especially, its cognitive demands, will change as a task passes through these phases. Tasks can be identified as high- or low-level of cognitive demand (Henningsen & Stein, 1997) according to the characteristics (Stein, Smith, Henningsen & Silver, 2000). There are



[Figure 1] The Mathematical Tasks Framework (Henningsen & Stein, 1997) two kinds in each level: *doing mathematics* tasks and *procedures with connections* tasks in high-level and *procedures without connections* tasks and *memorization* tasks in low-level. This framework guides analyses for this study.

This study attempts to explore how mathematics teachers' adaptations of a reform-oriented mathematics curriculum material, *Everyday Mathematics*, influence students' opportunities to learn mathematics in the elementary level. I illustrate first how teachers modify the curriculum material and then how such modifications influence the students' opportunities to learn mathematics in their mathematics classrooms in the following sections. In particular, the cognitive demand of tasks in the curriculum material, tasks as set up by teachers, and tasks as enacted by the teacher and students are examined. In doing so, teachers' adaptations of the material are revealed. Then, I search for how such adaptations affect students' mathematical learning opportunities.

III. Methods

This study is a part of a larger study investigating curriculum-based district-wide reform in elementary mathematics in the USA. For this particular study, one urban district with a particular elementary mathematics curriculum was selected; data were collected for second semester of the first year of the adoption of a reform-oriented elementary mathematics curriculum. Eight elementary teachers-2 Kindergarten, 4 Grade 1, and 2 Grade 2-from four different schools participated in this study at the specified time; they were all recommended by their principals in their schools and agreed to participate in the study. All of the teachers were observed two lessons in a row for the semester; 15 lessons were available to use for analysis for this study. The sources of data were collected through classroom observations and pre- and post-observation interviews in public elementary schools in a large urban city in the USA. The classroom write-ups consisted of a detailed lesson narrative followed by answers to an analytic set of questions about the mathematics classrooms. The interviews with teachers included questions about how the teacher prepared for and reflected upon the observed set of lessons with special attention to the role of curriculum materials. In addition, copies of *Everyday Mathematics* lessons on which the lessons are based were collected along with any classroom artifacts.

The data analyses involved several steps: a) analysis of curriculum materials in terms of cognitive demands of the tasks on which the lessons observed were based and learning goals and suggestions; b) analysis of the field notes of classroom observations in which two researchers were involved; c) analysis of the tasks that were identified as not maintaining the cognitive demand of tasks as either setup and enacted; and d) analysis of teachers' alterations from the curriculum material and students' learning during the lessons. Basically, all of these data were analyzed in terms of cognitive demands of tasks in the curriculum material, set up by teachers, and implemented in the lessons by students and teachers according to the task analysis guide suggested by Stein et al. (2000, p. 16). In analyzing the classroom observation field notes, one task that took up most of the time of each lesson was identified first. It ended up identifying 15 mathematical tasks in total and then analyzed them. In addition, classroom observation field notes were analyzed in terms of what the teachers did by examining the curriculum material, *Everyday Mathematics*. Finally, the data were analyzed in terms of what students did and learned in the classrooms as a result of the teachers' adaptations. In so doing, the curriculum material on which the 15 mathematical tasks identified from the earlier stage of analysis were based was thoroughly investigated to uncover learning goals that is intended to achieve through activities, tasks, and suggestions in the material. The curriculum material provides learning goals for each lesson in a form of overview of each chapter and statements in each lesson. Also, the tasks in the curriculum material were analyzed in terms of cognitive demand.

IV. Results

The goal of this study was to explore how the teachers' alterations of the suggestions in the curriculum material affect the students' opportunities to learn mathematics in their mathematics classrooms. Each lesson in *Everyday Mathematics* consists of 3 big sections (*Teaching the Lesson*, *Ongoing Learning & Practice*, and *Options for Individualizing*). As an introduction or warm-up activity, the material consists of: a) *summary* of the lesson; b) *materials* for the lesson; c) *mental math*; and d) *math message*. Teaching the Lesson begins with *math message follow-up* followed by additional tasks or activities. With regard to teachers' adaptations of the curriculum material, first, most of the teachers appeared to omit *math message* or *math message follow-up* tasks even after they did *math message* tasks. *Math message follow-up* involves discussion, exploration, and investigation for conceptual understanding. Further, the curriculum material suggests that what teachers should do and ask for deep understanding of mathematical concepts and ideas. The material also suggests teachers to encourage students to share their ideas, solutions, and strategies in solving problems. Next, similar to the result in which the level of cognitive demands of tasks were identified in both curriculum and enactment in the classroom, teachers seemed to set up tasks less cognitively demanding than as suggested in the curriculum material. *Doing mathematics* or *procedures with connections* tasks became *procedures without connections* or *memorization* tasks in the set up phase.

The results reveal that 5 teachers among the 8 participants seemed to alter their lessons either at the set-up phases or the enacted phases. The level of cognitive demands of tasks was changed from the tasks appeared in the curriculum material to the tasks as set up or tasks as implemented during the instruction. Specifically, 15 mathematical tasks were analyzed at the three phases according to the Mathematical Tasks Framework. As a result, 87 percent (13 out of 15) of the tasks as appeared in *Everyday mathematics* were identified as high-level, dominantly comprised of *procedures with connections* tasks. All of the high-level tasks as suggested in the curriculum material, however, were not maintained as was at the set-up by the teachers; 4 tasks (31 percent) were categorized as low-level at the set up phase.

The results from data analysis suggest that the teachers with *Everyday Mathematics* did not appear to maintain the cognitive demands of the tasks as it appears in the curriculum material and as it is enacted in the classrooms. That is, the teachers with *Everyday Mathematics* showed a tendency of declination into low-level in the transition from the curriculum to enactment. The cognitive demands of the tasks in *Everyday Mathematics*, especially, were mostly identified as *procedures with connections* tasks as described above. The enacted tasks were, however, identified as *procedures without connections* tasks or *memorization* tasks (80 percent, 12 out of 15 tasks), which are the low-level of cognitive demand. This shows that student learning occurred at low level in ways that the students were encouraged to learn procedures without understanding or memorize rules, facts, or algorithms to accomplish tasks. For example, a task for second graders in *Everyday Mathematics* focuses attention on the procedure for representing 3- and 4-digit numbers with base-10 blocks, but in a meaningful context by connecting place value in base-10 blocks with money. However, the task was enacted in the second grade classroom as *procedures without connections* to meaning, concepts, or understanding. Terry (pseudonym), the teacher, and the second grade students were engaged in the task procedurally; there were no explanations about representing the numbers with base-10 blocks. The students wrote down those numbers given on their worksheets without understanding. In addition, Terry just explained that "you read it from left to right, like anything else that you read" when the students read numbers right to left. Thus, the students appeared very confused and not to understand why and how they present numbers; they did not seem to develop mathematical thinking in doing this task.

Similarly, a doing mathematics task for developing place value concept as appeared in the curriculum material was enacted as memorization in a first grade classroom in which the enacted tasks involved reproducing previously learned definition of the place value. Emily (pseudonym), the teacher, wrote numbers on the board and asked students what number is in ones, tens, hundreds, and thousands place, which does not involve any thinking of students, not having the children "read them by stating the place value of each digit." Once the students memorize the place value, they could answer to the teacher's question. There were no connections to the concepts underlying the place value concept. The teacher did not give any explanations about the place value and ask the students to verify or explain their answers.

The teachers' adaptations seemed to affect the students' mathematical learning opportunities. First, the students did not have an opportunity to think and understand mathematics conceptually. For instance, the relationship among base-ten blocks for conceptual understanding of place value, various ways of representing numbers with base-ten blocks and the efficiency of the place value system. The students might have learned how the place value system works as working with base-10 blocks if they were taught as suggested in *Everyday Mathematics* by doing the *math message* for place value. The students could easily see and find the relationship by playing and examining the base-10 blocks when they were encouraged. Further, the first graders in Emily's (the teacher) classroom did not have opportunities to develop the understanding of place value in relation to money that they were used to in the real world; they could learn relationship among the money (10 pennies = 1 dime, 10 dimes = 1 dollar, and the relationship of penny and dollar) and connect to the understanding of place value. Through this activity suggested in the curriculum material, the students might be able to count by groups of 10, which is important to understand base 10 grouping that should be integrated with written names of numbers. The students did not have opportunities to check if they understand the place value by reading numbers when stating the place value of each digit. Emily's approaches seemed to force them to memorize the place value, rather than develop the meaning and understanding of the concept of place value. The first graders also did not have opportunity to think about various ways of representing numbers with base-10 blocks and the place value system as an efficient way to represent and write numbers. They may bring the idea of trading in performing it. Then the students would have developed better understanding the system of place value and not have to memorize the place value.

Likewise, Maggie (pseudonym), a first grade teacher, in another first grade classroom altered the intended curriculum by omitting a follow-up activity, which resulted in that the first graders did not have opportunities to show a number in various ways. The curriculum material suggested that the teacher ask the students to show 53 in another ways and discuss why those different ways represent the same 53. The experiences of representing 53 in various ways with base-10 blocks and discuss on it may give the students an opportunity to make sense of and develop the concepts of grouping by tens, recognizing such a group as a unit, and how numbers are written in the system of place value. This led the students to miss the opportunities to integrate the concept of grouping by tens with written numbers by not being guided to write numbers for the display of the base-10 blocks on the place value mat. The students also missed opportunities to develop and construct their meaningful understanding of the concept of place value. Those may give them more chances to practice writing numbers for given representations of the base-10 blocks and ordering numbers.

In addition, the students were not provided to learn about number 0 as teachers did not cover the concept that is suggested in the curriculum. The students could easily relate 0 to their experiences in everyday life as nothing or emptiness for a certain place value, which is important in place value and should be given in a context in which they can make sense of 0.

Importantly, the students did not have opportunities for mathematical thinking; rather, they were reinforced to learn procedures without connections to meaning and concepts and to memorize rules and procedures. When working on a task involving equivalent fractions that focus on students' understanding of the relationship between $\frac{1}{2}$ and $\frac{3}{6}$, second graders did not have opportunities to make sense of how the two numbers are equivalent ($\frac{1}{2}=\frac{3}{6}$) with a chocolate bar. That means $\frac{1}{2}$ and $\frac{3}{6}$ of a bar represents the same amount of the bar. However, the students were expected to only divide the chocolate bar into 6 pieces. Instead of having the students make connections between the two fractions, the teacher, Kathy (pseudonym), told them $\frac{3}{6}$ is the same as $\frac{1}{2}$. It would have been easier for the students to make connections between $\frac{1}{2}$ and $\frac{3}{6}$ if they were provided fraction cards as suggested in the curriculum material. The second grade students could figure out the relationship between the two numbers and why they are the same by working with fraction cards because they could easily compare the pieces of $\frac{1}{2}$and $\frac{3}{6}$. They were just expected to divide a chocolate bar into pieces and were told the two fractions were the same. Further, Katherine started with "which is more, eating $\frac{1}{2}$ of the cake or $\frac{2}{4}$? Explain." in the next day's lesson. This was not suggested in the curriculum material. It seems, however, that she changed numbers in the previous *math message* of "which is more: $\frac{1}{2}$ of a granola bar or $\frac{3}{6}$ of the same granola bar?" Further, she had the students work with play dough to find out which is more: $\frac{1}{2}$ or $\frac{2}{4}$ of a cake. Then, she discussed the activity as a whole group. Given different numbers in the same context, the students would have had opportunities to develop understanding equivalent fractions. The students did not appear to understand why $\frac{1}{2}$ equals to $\frac{3}{6}$ of a chocolate bar in the prior lesson. In this following lesson, they were expected to work with concrete materials such as play dough to have $\frac{1}{2}$ and $\frac{2}{4}$ and then compare them. The students, however, did not have opportunities to develop understanding and extend the concepts of fractions. The activities suggested in the curriculum material focused on finding equivalent fractions with fraction cards, writing with numbers, matching fractions with pictorial representations, and practicing their understanding of what fractions mean and show with multiple representations of collections of objects.

V. Conclusions & Implications

This study investigated how elementary mathematics teachers' alterations of the curriculum material affect students' opportunities to learn mathematics. The results show that the teachers' adaptations of a reform-oriented mathematics curriculum material influenced the ways students learn and understand mathematical concepts and do mathematical tasks negatively. The influence seemed to violate the intention of the curriculum material. That is, teachers' alterations decreased students' mathematical learning opportunities; the students appeared to miss opportunities to learn mathematics conceptually as well as perform procedures with connections to meaning. For example, the first and second graders were not encouraged to explore the meaning of place value even when working with concrete materials such as base-10 blocks and place value mats. Thus, they did not have opportunities to develop the place value concept, which may result in the students' difficulties in performing the computation of numbers later on. Despite that understanding the concept of place value is critical in further the learning of mathematics with understanding in the elementary level, the students were promoted to carry out procedures and even to memorize, not to understand the concepts.

Interestingly, teachers in pre- and post-interviews said that they closely followed the curriculum material, Teacher's Guide in this case. The ways they set up and enacted in their classrooms, however, did not appear to follow closely; rather, they partially took tasks, suggestions, examples, and questions (Kim, 2011). This result confirms that maintaining high-level tasks as enacted is not an easy work (Henningsen & Stein, 1997). The results of this study also confirm that teachers using reform-oriented curriculum materials that are demanding for teachers have difficulty maintaining the cognitive efforts of students in learning mathematics (Smith, 2000; Stein & Kim, 2009).

Further studies should attempt to reveal that what keeps the teachers from following the suggestions of the curriculum material meaningfully. In addition, further studies need to explore what makes teachers tend to adapt to a degree that decreases the level of cognitive efforts. For further research, it is necessary to reconsider teacher knowledge for teaching mathematics, particularly, teachers' capacity to perceive and mobilize resources in the curriculum material meaningfully (Brown, 2009).

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수학수업에서 교사의 교과서 및 교사용지도서 변형 및 활용이 학생의 수학학습에 미치는 영향

김구연[3]

요 약

수학교사가 수학교육 개선을 위해 NCTM가 제안한 Standards를 적용하여 개발된 교육과정을 수학 수업에서 어떻게 적용하는지 그리고 그 적용과정에서 교사의 조정이 학생들의 수학 학습에 어떤 영향을 미치는지 살펴보고 분석하는 것이 이 연구의 목적이다. 이를 위하여 미국 초등교사 8명의 수업관찰 기록과 관찰된 수업에서 활용된 *Everyday Mathematics*의 교과서와 교사용 지도서 그리고 면담자료를 수집하고 분석하였다. 수업관찰 기록과 *Everyday Mathematics*의 교과서와 교사용 지도서는 활동과제 (task)별로 코딩하고 분석하였다. 또한 교육과정에 나타난 활동과제, 교사가 구성한 활동과제, 실제 수업에 적용된 활동과제를 각각 분류하고 분석하였다. 그 결과 교사들의 구성과 적용에서 교육과정에서 제시한 수준과 다르게 나타난 활동과제를 찾을 수 있었다. 또한 이러한 활동과제들의 인지 처리수요 (cognitive demand) 수준이 감소되는 것으로 나타났다. 그러한 변화 혹은 조정은 수업시간에 학생들의 수학학습에 영향을 주는 것으로 드러났다. 학생들은 수학의 개념을 개념적으로 혹은 의미 있게 사고하고 이해할 수 있는 경험을 하지 못하고 오히려 절차적으로 문제를 풀고 때로는 암기를 통해 문제를 해결하는 경험을 더 많이 하는 것으로 나타났다.

주요 용어: 수학 교육과정, 학생의 수학학습 기회, 실행된 교육과정, 교사의 교육과정실행, 초등학년

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