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ABSTRACT

This study probes in what ways the teacher and students create unequally successful student-centered mathematics classrooms and what kinds of learning opportunities arise for the students in these classrooms. A general guideline to the understanding of mathematics classroom culture is an emergent theoretical framework that fits well with the reform agenda for instruction. Findings of mathematics teaching and learning in five different classrooms, importance of sociomathematical norms, and implications for reform in mathematics education are discussed in this report. (KHR)

Understanding The Culture of Elementary Mathematics Classrooms In Transition[1]

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Background to the Study

Educational leaders have sought to change the prevailing teacher-centered pedagogy of mathematics to a student-centered pedagogy (NCTM, 1989, 1991, 2000). The term *teacher-centered* refers to a teacher's explanations and ideas constituting the focus of classroom mathematical practice, whereas the term *student-centered* refers to students' contributions and responses constituting the focus of classroom practice. Instead of listening and following a teacher's instruction, the students in a reform-oriented classroom are expected to have the opportunity to be enculturated into a mathematical discourse in which they invent, explain, and justify their own mathematical ideas and critique others' ideas.

The reform movement has been successful in marshaling large-scale support for instructional innovation, and in enlisting the participation and allegiance of large numbers of mathematics teachers (Knapp, 1997). In contrast to the widespread awareness of reform, there has been a growing concern that many teachers have not grasped the vision of the current reform ideas (Kirshner, 2002; Research Advisory Committee, 1997). Teachers often interpret reform as a new list of teaching strategies and materials, rather than regard the reform as a way to re-conceptualize their understanding of mathematics and its teaching. They too easily adopt new teaching techniques such as the use of real-world problems or cooperative learning, but without reconceptualizing how such a change in teaching strategies relates to fostering students' conceptual understanding or mathematical dispositions (Burrill, 1997; Stigler & Hiebert, 1998). This is true even for teachers who are committed to implementing reform recommendations (Fennema & Nelson, 1997; Lampert, 2001). The real issue is then to understand not the form but the quality of an instructional method - What kinds of mathematical and social exchanges occur and in what ways such changes promote students' mathematical development?

Korean students have consistently demonstrated superior mathematics achievement in recent international comparisons (e.g., Beaton et al, 1996; Millis et al, 2000). Despite the high performance, the problems in Korea with regard to mathematical education are perceived to be similar to those in other countries. Such problems include learning without deep understanding, negative mathematical disposition, weak problem solving ability, and lack of creative mathematical thinking. These problems may come from many factors associated with legal and cultural aspects of Korean society, and hence present no immediate prospects for change.

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However, teacher-centered instructional methods[3] have been critiqued and broad-scale efforts have been launched to influence the ways mathematics is taught. The most recent national curriculum and concomitant textbooks with teachers' guidebooks consistently recommend student-centered teaching methods (Ministry of Education, 1997).

Whereas typical teaching practices in U.S. mathematics classrooms have been extensively studied through microanalysis of video-recordings of mathematics instructions, those of Korean mathematics classrooms have been little studied in the international contexts. An exceptional study conducted by Grow-Maienza, Hahn, and Joo (1999) reports:

> Teacher behaviors are dominated by question/answer patterns and demonstration of operations in many modes and patterns which lead students through the procedures and conceptual development of the problem, at the same time facilitating student thinking. Student behavior is characterized by choral responses and choral evaluation of individual responses which keep students on task. (p. 6)

Given the challenges of implementing reform ideals, this study deals with reform-oriented classrooms, not typical ones. Moreover, this study is to understand better the *processes* that constitute student-centered pedagogy in elementary mathematics classrooms in Korea. However, this study makes a significant departure from previous research trends on reform where single reform-oriented classroom is extensively studied (e.g., Ball, 1993; Cobb & Bauersfeld, 1995). Close contrasts and comparisons of unequally successful student-centered classes have rarely been conducted in previous research on reform (cf, Carpenter, Franke, Levi, 1998; Pang, 2000). Such comparisons can provide a unique opportunity to reflect on the subtle but important problems and issues of implementing educational reform at the classroom level. This study is intended to gain insights on the challenges for reformers -- including educators, policymakers, administrators, and educational researchers -- in changing the culture of primary level mathematics instruction.

Theoretical Framework

This study probes in what ways the teacher and students create unequally successful student-centered mathematics classrooms and what kinds of learning opportunities arise for the students in these classrooms. A general guideline to the understanding of mathematics classroom culture is an "emergent" theoretical framework Cobb and his colleagues developed that fits well with the reform agenda for instruction (Cobb & Bauersfeld, 1995). In this perspective, mathematical meanings are neither decided by the teacher in advance nor discovered by students; rather they *emerge* in a continuous process of negotiation through social interaction.

[3] There may be differences between Korean and the U.S. mathematics instruction under the same rubric "teacher-centered." For instance, typical Korean teachers orchestrate their teacher-centered lessons more systematically, coherently, completely, and progressively than U.S. counterparts do (Grow-Maienza, Hahn, & Joo, 1999). It is very noticeable in comparison with U.S. students that Korean students are deeply engaged in teacher-centered lessons and enthusiastically provide choral responses. However, Korean mathematics instruction is indeed teacher-centered in the same way to U.S. instruction in that teachers' explanations and directions constitute the mainstream of mathematical practices.

Along with the emergent perspective, two constructs of *social norms* and *sociomathematical norms* are mainly used to characterize each mathematics classroom. General social norms are the characteristics that constitute the classroom participation structure. They include expectations, obligations, and roles adapted by classroom participants as well as gross patterns of classroom activity (Cobb & Yackel, 1996). For example, the general social norms in a student-centered classroom include the expectation that students invent, present, and justify their own solution methods.

Sociomathematical norms are the more fine-grained aspects of these general social norms that relate specifically to mathematical practices (Yackel & Cobb, 1996). The examples of sociomathematical norms have included the norms of what count as an acceptable, a justifiable, an easy, a clear, a different, an efficient, an elegant, and a sophisticated explanation (Bowers, Cobb, & McClain, 1999; Cobb, Gravemeijer, Yackel, McClain, & Whitenack, 1997; Yackel & Cobb, 1996). For instance, the sociomathematical norms in a student-centered classroom may include the expectation that students are to present their solution methods by describing actions on mathematical objects rather than simply accounting for calculational manipulations.

The construct of sociomathematical norms is intended to capture the essence of the mathematical microculture established in a classroom community rather than its general social structure (Yackel & Cobb, 1996). The differentiation of sociomatheamtical norms from general social norms is of great significant because interest is given to the ways of explicating and acting in mathematical practices that are embedded in classroom social structure. However, previous studies tend to briefly document sociomathematical noms (and social norms) mainly as a precursor to the detailed analysis of students' conceptual learning established in the classroom community (Pang, 2001).

Given the challenges of implementing reform ideals, the sociomathematical norms construct can be critical in understanding whether or not reform-oriented teachers use classroom social structure effectively to develop students' mathematically significant beliefs and values and to enhance their conceptual understanding of mathematics. In this respect, this study pursues the possibility that the breakdown between teachers' adoption of reform objectives, and their successful incorporation of reform ideals implicates the sociomathematical norms that become established in their classrooms.

Methodology and Procedures

This study is an exploratory, qualitative, comparative case study (Yin , 1994) using *constant comparative analysis* (Glaser & Strauss, 1967; Strauss & Corbin, 1998) for which the primary data sources are classroom video recordings and transcripts (Cobb & Whitenack, 1996). The data used in this paper are from a one-year project of reform in elementary schools in Korea. As a kind of purposeful sampling (Patton, 1990), the classroom teaching practices of 15 elementary school teachers eager to align their teaching practices to reform were preliminary observed and analyzed. An open-ended interview with each teacher was conducted to investigate his or her beliefs on mathematics and its teaching. This extensive search was needed, given the recency of the reform recommendations, and the infrequently of teachers' explicitly advocating reform allegiances.

Five classes from different schools were selected that clearly aspired to student-centered classroom social norms. Two mathematics lessons per month in each of these classes throughout the year were videotaped and transcribed. Individual interviews with the teachers were taken three times to trace their construction of their teaching approaches. These interviews were audiotaped and transcribed.

Additional data were from monthly inquiry group meetings in which the teachers watched together their videotaped teaching practices and discussed mathematics, curriculum, and pedagogy. The purpose of the inquiry meetings was not to tell what student-centered teaching practices looked like from outsiders' perspectives, which might lead the participants to pick up some specific teaching techniques. Instead, the meetings were intended to serve as an inquiry community in which the teachers might look closely at their own teaching practices as well as others and treat them as generative materials for interpretation and interrogation toward reform-oriented instruction. In general, the interview and inquiry group data were to understand the successes and difficulties that might occur in the process of changing the culture of mathematics classrooms, as well as the recursive relationship among the teachers' learning, beliefs, and classroom teaching.

Data analyses have two stages: Individual analysis of each classroom and comparative analysis. Because case study should be based on the understanding of the case itself before addressing an issue or developing a theory (Stake, 1998), teaching practices are very carefully scrutinized in a bottom-up fashion. The central feature of these analyses is to compare and to contrast preliminary inferences with new incidents in subsequent data in order to determine if the initial conjectures are sustained throughout the data set (Erickson, 1986; Glaser & Strauss, 1967). Next, the data from the individual classes are employed for comparisons among the unequally successful reform instruction.

Results

A preliminary analysis shows that the five classrooms display similar general social norms that are compatible with current reform recommendations (Ministry of Education, 1997; NCTM, 2000). The teachers established open and permissive atmosphere in which students' ideas and their mistakes were welcomed. The classes were dynamic in that students actively responded to the teacher and one another. The teachers frequently used a small group format and emphasized group cooperation. They also provided encouragement and positive expectations for the students' accomplishments. The discussion pattern of social interaction predominated with a sequence of teacher-student turn taking. Moreover, each lesson consistently consisted of the brief review of the previous lesson, the teacher's introduction of new mathematical contents or activities, students' activities, and whole-class discussion. Three among the five classes are described below in order to focus on the difficulties and successes of the teachers, and to formulate issues and obstacles that may point toward generic problems of reform. The three teachers are identified as Ms. S, Ms. Y, and Ms. K. Whereas Ms. S was 5th grade teacher, the other two teachers were 6th grade ones.

Mathematics Teaching and Learning in Ms. S' Classroom

In many ways, Ms. S encouraged students' participation in the classroom mathematics activities and discussions. For instance, she lavished praise and positive expectations on the students, informed them of the interesting history of relevant mathematical topics, and emphasized various solution methods to a given problem. Among other things, she gave students many opportunities to solve problems individually or collectively and to present their methods to the class. She often allowed them to spend a lot of time in solving and discussing one problem. For instance, throughout two class periods, Ms. S encouraged students to come up with multiple ways of figuring out the area of a trapezoid on the basis of their prior knowledge of other figures. She prevented students from applying the memorized formula of the area. Reflecting Ms. S' practices, the students were eager to present their own thinking and solution methods.

In many cases, however, the content and qualities of the classroom discussion were rather unfocused or unproductive because Ms. S tended to accept all students' contributions without any mathematically significant distinctions or connections. To be clear, in some cases, Ms. S expressed her mathematical interest but those cases were somewhat infrequent. In solving 2.4 divided by 2, a student drew 2 longs and 4 units, and colored half of them (i.e., 1 long and 2 units), explaining "because it's 2.4 divided by 2, when you divide 2 [longs], you get two of 1 long each. Because it's 2.4, you still have the 4 [units]. When you divided them by 2, you get 2 [units] each so I colored only two of the four." Ms. S immediately paid attention to the size of longs and units, pointing out that the student should have written 0.4 instead of 4 for the picture of 4 units, because she regarded the long as 1 instead of 10. Ms. S took this opportunity to emphasize that mathematics should be accurate. However, she did not connect the diagram with the numerical expression of $2.4 \div 2 = (2 \div 2) + (0.4 \div 2) = 1 + 0.2 = 1.2$, presented by another student, nor with the standard algorithm of long division she emphasized later. Ms. S appeared to be satisfied with the fact that her students solved the problem in various ways and reached at the correct answer with adequate language.

In other cases, Ms. S listened to students' various contributions but usually turned out to control the classroom discussion directing it towards a particular orientation by expressing her expectation of what students would present. This often led the students to guess the teacher's expectations rather than to pursue their own understanding.

Although Ms. S emphasized various solution methods and representational modes, she frequently checked whether such methods produced the same correct answer and rarely probed the nature of students' understanding or ideas. For instance, when asked to find out solution methods of 12.48 divided by 8 using diagrams, fractions, and/or division algorithms of natural numbers (i.e., 1248 divided by 8), a student drew a line with the length of 12.48 and divided it into 8 segments with the length of 1.56 each. The student explained that she first drew a line of 12.48 and then divided it into 8. Ms. S checked the right answer 1.56 but did not probe how the student figured out the answer (e.g., whether the student used the diagram in order to figure out the quotient or calculated numerically and then represented it in the diagram.) In general, there was little discussion of why different methods worked, how they were related to each other, or even why different methods were important to study.

Whereas the students were actively involved in classroom mathematical activities, they had little chance to develop the mathematical understandings that could inform their activities.

They had limited learning opportunities with regard to the transition from informal to formal strategy of doing computation or understanding mathematical principles. The important sociomathematical norms of this class were concerned with mathematical accuracy.

Mathematics Teaching and Learning in Ms. Y's Classroom

Ms. Y was the teacher who experienced gradual but dramatic changes in her teaching practice. She was eager to participate in the project, revealing her interest in student-centered teaching practice. To be clear, the preliminary observation of her instruction illustrated that her general teaching approaches would be consistent with the current reform ideas, evidenced by the general common social norms described above. However, she was very concerned about going through all the activities and problems in the textbook. At first, she faithfully followed the sequence of activities in the textbook, not necessarily recognizing the interrelations among them. The students complied with the teacher's instruction and had little opportunity to develop their own thinking.

A noticeable change in Ms. Y's teaching practice occurred after she had an opportunity to see another teacher Ms. K's instruction in the first inquiry group meeting. Because the two teachers were 6^{th} grade teachers, Ms. Y could see more directly how teachers' different approaches even with the same contents and materials would result in different learning environment on the part of students' mathematical development. In particular, Ms. Y expressed her excitement about the variety and the depth of the students' mathematical ideas and thinking in Ms. K's classroom. In the inquiry meetings, Ms Y was very active in discussing Ms. K's teaching practices with her students' learning.

Instead of relying heavily on the textbook, Ms. Y started to develop a worksheet intended for students to explore important mathematical ideas. She allowed students more time to develop their own sense-making and to explain their thinking to the class. For example, in the lesson about the relationship between the circumference and the diameter of a circle, Ms. Y encouraged the students to think about how to measure circumferences and to find out the relationship between circumferences and diameters with various circles. Ms. Y was enthusiastic to share her teaching experience with exemplary students' work in the subsequent inquiry meetings.

Ms. Y indeed asked for different solution methods to a given problem or activity. She then frequently facilitated students to compare and contrast similarities and differences among the various methods. Meanwhile she differentiated mathematical differences (e.g., difference of mathematical principles applied to solve a problem) from physical or visual differences (e.g., difference of materials or representational modes used).

Despite the promising transition toward more successful student-centered teaching practices, Ms. Y had some difficulties when students reacted anxiously to the uncertainty associated with the given activity or they did not come up with a specific idea that the teacher thought was important. In those cases, Ms. Y provided a crucial hint that might change the nature of the given task or introduced her own solution strategies, instead of letting students invent them. In addition, Ms. Y was not sure of how to react to students' novel ideas except praise. She was also frequently struggled with how to balance the encouragement of students' conceptual development and the teaching of efficient procedures such as standard algorithms. After listening to students' various solution methods, Ms. Y usually ended her lessons by summarizing or formulating the most efficient one and implied the students to use it in solving problems for practice.

Mathematics Teaching and Learning in Ms. K's Classroom

Ms. K was more successful teacher than Ms. Y in that she consistently developed mathematically significant agendas in the course of supporting students' engagement and discussion. Because almost all Korean teachers use the reform documents such as mathematics textbooks and teachers' guidance books as the main instructional resources (Kim et al, 1996), Ms. K employed a lot of the same activities as what Ms. Y did. However, Ms. K tended to focus on one or two activities that were mathematically important and gave students enough time to develop and discuss their own ideas. Unlike Ms. Y, Ms. K was very confident in re-constructing the activities or their sequences in the textbook for her instructional purpose. For example, when the textbook introduced a basic idea of permutations and provided many problems for practice, Ms. K spent considerable time in *differentiating* permutations from combinations with real-life contexts, rather than checking the correct answers of the problems.

Ms. K's mathematical interest was also evident in facilitating the whole class discussion after the individual or collective problem solving. Ms. K carefully observed students' work and picked out mathematically insightful contributions for presentation. She encouraged students to present their solution methods but had a tendency of filtering their multiple ideas to pursue mathematically significant ones, rather than applauding all contributions equally. She often posed a more challenging problem based on students' contributions. In this way, the quality of mathematical discourse in Ms. K's class was much more sophisticated and powerful than that of Ms. Y's class.

Ms. K usually explained in detail what the given problem or activity was about and made sure whether or not the students understood it. She also explained what the students should think about during the activity phase, rather than letting them to experience unfocused exploration or retrospective review of the activity. For example, in the lesson about the ratio of the circumference of a circle to its diameter, Ms. K pushed the students to identify the variants and invariants as the sizes of circles varied and to be ready to explain and justify what they discovered throughout the activity. This prevented students from simply stating the fact that the circumference of a circle divided by its diameter is about 3.14, which might have been known to most students because of their preparation of the lesson.

Of special importance in Ms. K's class was the connection between visual representations and numerical representations. Like the other teachers, Ms. K called for various solution methods to a given problem. Students often solved the problem by drawing a diagram and Ms. K consistently asked them to add an appropriate numerical expression to the diagram. This enabled students to see the meaning of complex computations such as the division of mixed fractions or that of a fraction by a decimal. In these ways, the students had the learning opportunities to construct conceptual underpinnings of the mathematics they were studying, even as they were continually exposed to mathematically significant ways of knowing, valuing, and arguing.

Discussion

Importance of Sociomathematical Norms

Despite the exemplary *form* of student-centered instruction, the content and qualities of the teaching practices described above were somewhat different in the extent to which students' ideas become the center of mathematical discourse and activity. The students in Ms. S' classroom actively participated in the classroom activity and discourse but had limited opportunity in terms of developing the conceptual sense of the mathematics they were studying. In order words, the class has developed a reasonable discourse structure, but one that does not reflect the culture of mathematical inquiry. In contrast, Ms. Y and Ms. K carefully orchestrate the path of discourse towards conceptual understanding, leading the students to be continually exposed to mathematically significant distinctions in their classroom microculture. This clearly shows that learning opportunities within the three classrooms were very much constrained not by the classroom participation structure per se but by the mathematically significant engagements within the structure. In other words, the dynamic engine of learning opportunities was not located in the general social norms of the classroom. Rather learning opportunities arose from the ways in which mathematically significant distinctions were embedded within classroom social processes. In line with many commonalities in the challenges of reforming mathematics classroom culture, therefore, this study addresses the need for a clear distinction between attending to the social practices of the classroom and attending to students' conceptual development within those social practices.

Teacher Learning in a Community

A preliminary but noticeable change in Ms. Y's teaching practice channels our attention toward a collaborative community where groups of teachers are committed to raise questions on their current instruction, search for alternatives, try on new approaches, share with colleagues, and weigh their approaches against others' pedagogical alternatives for the common purpose of improving their teaching practices. In fact, many recent studies of teachers' attempts toward reformed mathematics teaching suggest the importance of an inquiry community that provides shared goals and collaboration (Cochran-Smith & Lytle, 1999; Fennema & Nelson, 1997). The message is that there may be a need to re-conceptualize aligning teaching to the reform, not primarily as an individual teachers' isolated accomplishment, but as a community's collaborative enterprise.

The different influence of the community on the two teachers' teaching practices (i.e., Ms. S and Ms. Y) makes us consider the benefits of participating in a supportive community. Some benefits may include teachers' sense of a collective responsibility for students' learning, shared resources, increased instructional expertise, and reduced feelings of isolation. However, Ms. S case stimulates us to articulate the nature and the functioning of collaboration. The common culture that are nonjudgmental rather than critical of others' teaching practices may provide psychological and social support for teachers such as Ms. S, but not necessarily professional or intellectual support that teachers need to transform their teaching practices. In working together in a supportive community for reform, participants need to establish new norms for discourse concerning their instructional changes, obstacles and dilemmas of change, as well as the more general nature of mathematics teaching and learning. While accepting the importance of supportive communities for teachers, there is a need to explore the ways such communities provide teachers with opportunities to challenge their teaching practice, and to discover how participants perceive their collaboration with one another.

Implications for Reform

Changing the culture of the mathematics classroom is fundamentally about significant transition, and the transition is an active never-ending process. The extent to which significant change occurs depends a great deal on how the teacher comes to make sense of reform and respond to it. Detailed descriptions of the processes that constitute unequally successful student-centered pedagogy at the classroom level are intended for teachers to be empowered in developing alternatives or integrating different aspects of reform agenda with regard to their own diverse pedagogical motivations.

This study shows how difficult it is to see fundamental instructional changes in mathematics classrooms, even with teachers who are committed to implementing reform recommendations. Teachers tend to wait to be told the "right" way to teach mathematics and are eager to change their old teaching strategies in order to implement new ones that have been advocated in the current reform era. However, such a passive action does not guarantee that students are engaging in creative and reflective mathematical activities. Teachers are expected to use the social structure of the classrooms to nurture students' development toward mathematical ways of thinking as well as their understanding of specific mathematical concepts and processes. This coordination requires new ways of thinking about the teaching/learning dynamic. Re-conceptualizing teaching and learning can pose great difficulty for teachers whose previous experience has been in implementing traditional teacher-centered instruction- even if the teachers are eager and willing to teach differently. But these challenges must be met by teachers and teacher educators if the reform intentions are ever to be realized.

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