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Fanning the Flames of Greatness

In This Issue, We Offer Ideas for Extending Your Passion to Other Mathematics Professionals

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Table of Contents

CORRECTION FROM WINTER 2008 JOURNAL
The Winter 2008 *NCSM Journal* omitted co-author Daniel Clark Orey from the byline of the article, "It Takes A Village: Culturally Responsive Professional Development and Creating Professional Learning Communities in Guatemala." Dr. Orey is a professor of mathematics and multicultural education at California State University, Sacramento. We regret the omission.

Purpose Statement

The purpose of the National Journal of Mathematics Education Leadership is to advance the mission and vision of the National Council of Supervisors of Mathematics by:

- Strengthening mathematics education leadership through the dissemination of knowledge related to research, issues, trends, programs, policy, and practice in mathematics education
- Fostering inquiry into key challenges of mathematics education leadership
- Raising awareness about key challenges of mathematics education leadership, in order to influence research, programs, policy, and practice
- Engaging the attention and support of other education stakeholders, and business and government, in order to broaden as well as strengthen mathematics education leadership

The Influence of Standards-Based Curricula on Questioning in the Classroom

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This article explores the influence of nationally funded textbooks on the levels of questions posed in the classroom. Evaluations were made of the questions asked in courses taught with either a traditional text or a textbook from the *Core-Plus Mathematics Project* (CPMP). Analysis revealed that higher levels of questions occur more frequently in CPMP textbooks and the courses corresponding to their use. However, upon further exploration, it was evident that although textbooks may be the driving force for the classroom, they are not the sole factor in determining what transpires in the classroom. The results of this study may help guide other national and international organizations in their attempts to transform the levels of questions that are posed in typical classrooms.

Introduction

In the United States, the National Council of Teachers of Mathematics (NCTM) has published numerous standards documents in order to guide the reform of mathematics education. The most recent document that includes secondary level mathematics is the *Principles and Standards for School Mathematics* (NCTM, 2000). One of the primary roles and purposes of the *Principles and Standards for School Mathematics* (PSSM) is to guide the development of curriculum frameworks, assessments, and instructional materials (NCTM, 2000). However, it is up to the textbook publishers and authors to incorporate the concepts and methods introduced in those standards.

In response to NCTM's vision outlined in each of the standards documents, the National Science Foundation (NSF) challenged organizations to develop curricula materials that follow the framework for mathematical instruction set forth by the NCTM. One of the fundamental objectives of the NSF-funded projects was to improve the quality of learning and teaching of mathematics in classrooms (NSF, 1991). Several submissions were received by the NSF and eleven textbook series were created. The NSF had several reasons for choosing textbooks to assist in the implementation of the new standards. This paper will shed light on whether or not "standards-based" textbooks have an influence on the types of questions posed in the classroom. The interaction between the teacher and the textbook may be the most important factor influencing what transpires in the classroom. For this very reason, it is important to consider whether or not higher levels of questions are posed in classrooms where standards-based textbooks are utilized.

Textbooks have a profound impact on what takes place in the mathematics classroom. Senk has reported that student learning has been found to be more influenced by the text rather than the teacher (2003, p. 4). If textbooks have such a large impact on the way students learn mathematics, then it appears as though NSF responded to the standards set forth by NCTM in a productive manner. Without adequate textbooks to meet the standards, teachers would lack adequate resources to enact the vision of the standards. Teachers need assistance to create worthwhile tasks for their students to complete. One of the fundamental ways teachers can influence what transpires in the classroom is to ask appropriate questions. It is equally important to ask a wide-range of questions. The research of Bloom developed a taxonomy for classifying the levels at which questions are posed (1956). Bloom identified six categories in his taxonomy.

The six categories are knowledge (K), comprehension (C), application (AP), analysis (AN), synthesis (S), and evaluation (E). There have been some minor revisions to the order and names of categories, but the six listed date back to Bloom's original work. Bloom's original work served the purposes of this study in that it allowed the researchers to differentiate among the questions posed. Table 1 provides definitions as well as example questions for each of the categories.

As one might imagine, it is easier to construct questions at the lower levels (Knowledge and Comprehension), and more difficult to create higher-level (Application, Analysis, Synthesis, and Evaluation) questions. One would hope that NSF-funded textbook series were designed to provide teachers with a resource for selecting a range of question types, with an emphasis on higher-level questions. According to Moyer & Milewicz, "A good question may mean the difference between constraining thinking and encouraging new ideas, and between recalling trivial facts and constructing meaning" (2002, p. 293). Mathematics teachers in the United States are more prone to constrain students' thinking by asking questions that only allow for the practice of basic skills (Stigler & Hiebert, 1999). This pattern was documented in the Third International Mathematics and Science Study (TIMSS) videos. Lower-level questions that only require one word answers are frequent throughout the video samples provided of American classrooms (Moyer & Milewicz, 2002). According to Stigler & Hiebert, "the nature and tone of teachers' questions often give away the answer..." (1999, p. 45)

Research clearly shows there is room for improvement when it comes to the levels of questions posed in the mathematics classroom. NSF-funded, standards-based textbooks have been constructed in part to address this shortcoming. The foundation of these textbooks is providing tasks for students to develop high levels of mathematical thinking. Good tasks are those that provide an appropriate level of challenge and support for the students as well as lead students to the discovery of important concepts and problem solving techniques (Hirsch et. al, 1995). Tasks designed to develop students' higher-order thinking skills are provided by NSF-funded, standards-based curricula materials, but it is up to the teacher to implement those materials (Cai, 2003).

Research Questions

• How do the levels of questions posed in a standards-based textbook compare to the levels of questions posed in a traditional textbook?

Table 1

Category	Definition	Example Question
Knowledge	require students to recall previously-learned material	What unit do you use to measure an angle?
Comprehension	ask students to demonstrate understanding of a concept	In your own words, explain how an obtuse angle differs from an acute angle and from a straight angle?
Application	involve students using methods, concepts and theories in new situations	[Provide students with a set of angles – including right, straight, obtuse, and acute] Measure the following angles; classify the angles as acute, right, obtuse, or straight.
Analysis	require students to break down information into parts and support their decomposition	Suppose you were asked asked to determine if a given angle, A, could be formed by adding some number of copies of another angle, B. How would you determine if this were possible?
Synthesis	require students to put ideas together	Show that the sum of the measures of the interior angles in a triangle is 180°.
Evaluation	involve students making judgments about information based on a set of criteria	Person A showed that the sum of the interior angles of a triangle is 180° by measuring angles in several triangles and finding that the sum was always 180°. Person B showed that the sum of the interior angles of a triangle was 180° by cutting off the corners of a "random" triangle and putting the corners together, vertex to vertex and edge to edge, to show that a straight angle was formed. Which of these methods is a more valid demonstration of the interior angle sum of a triangle? Explain.

• What is the influence of the use of a standards-based textbooks on the level of questions posed in the classroom?
• What is the influence of the use of standards-based textbooks on the level of questions posed on teacher-constructed assessments?

Methodology

Participants

The participants in the study were seven high school teachers at a suburban high school in northwest Ohio. The school is located in the only school district within northwest Ohio that is using an NSF-funded textbook series at the secondary level. However, this school district is still teaching many course sections using traditional textbooks.

Courses and Textbooks

Since this school district implemented the use of CPMP, two years ago, only Course 1 and Course 2 were being taught at the time of this study. Course 1 is a freshmen level mathematics course that the district is using to correspond to the traditional Algebra Course. Course 2 is a sophomore level mathematics course that the district is using to correspond to the traditional Geometry course. Although two newer editions have been published since 1998 (2003, 2008), this edition was used for the purposes of this study since that edition was being used by the district at the time of this study. The text *Algebra 1* (Holiday et al., 2003) was used in the traditional Algebra course and *Geometry* (Boyd et al., 2004) was used in the traditional Geometry course. Since CPMP is an integrated mathematics curriculum, careful consideration was made in choosing units where the content of the lessons was similar.

Five of the seven teachers involved with this study teach traditional courses with the assigned text. Three of the five teach algebra, while the other two teach geometry. The remaining two teachers teach the non-traditional courses with CPMP. Each of these two teachers attended weeklong training seminars provided by the textbook company prior to the start of the academic year.

Instrumentation

The levels of questions posed in a CPMP textbook were compared with those posed in a traditional textbook. Comparable sections were selected. A Questioning Levels Evaluation Form developed by the researcher was used to evaluate the levels of questions posed in each textbook. This evaluation form was based on the six levels of questions identified by Bloom (1956).

The author/investigator observed each class involved with this study a total of five times. The date and time of each observation was chosen by the individual teachers. All classes lasted a duration of 42 minutes. The levels of questions posed during each class were transcribed and later evaluated using a Questioning Levels Evaluation Form developed by the researcher. This evaluation form was based on the six levels of questions identified by Bloom (1956). The categorization of the questions were corroborated by an independent reviewer. In the event there was disagreement between the researcher and the independent evaluator, a discussion was held to classify the question in the appropriate category.

Each teacher was asked to provide two representative tests for their course. These tests were collected to provide a sample of questions to determine what levels of questions were being used on assessments. These tests also provided insight into whether or not the levels of questions during observations were consistent with the levels of questions posed on assessments.

Each teacher was also interviewed to ascertain the individual teacher's values and beliefs in regard to mathematics education, as well as to determine their level of professional development associated with mathematics education.

Results

Textbook Question Evaluation

The first comparative analysis involved one investigation from the CPMP series and two sections from the traditional text. The focus of the investigation from the CPMP was on slope and direct variation (Coxford et al., 1998, Course 1, Part A, pp. 182-194). This investigation involved 100 questions over 12.5 pages. There were no worked out examples in this investigation. One section from the traditional text focused on slope (Holiday et al., 2003, pp. 256-262). This section posed 65 questions over 7 pages, and there were 10 worked out examples. The second section centered on the concepts of slope and direct variation, and asked 62 questions over 7 pages (Holiday et al., 2003, pp. 264-270). There were also 10 worked out examples in this section.

The second comparative analysis also involved one investigation from the CPMP series and two sections from the traditional text. The central theme of this investigation from CPMP was on point-slope form and finding linear equations in that form (Coxford et al., 1998, Course 1, Part A, pp. 194-199). This investigation asked students 33

questions over 5 pages, with no worked out examples. The first section from the traditional text discussed the concept of point-slope form (Holiday et al., 2003, pp. 272-277). This section posed 55 questions over 6 pages, with 8 worked out examples. The second section focused on writing linear equations in point-slope form (Holiday et al., 2003, pp. 280-285). There were 47 questions asked over 6 pages, with 4 worked out examples. The overall proportion of questions posed at each level is displayed in Table 2.

Table 2: Comparative Textbook Evaluation

Textbook	Traditional	CPMP
Knowledge	0.83	0.5
Comprehension	0.06	0.05
Application	0.09	0.40
Analysis	0.02	0.40
Synthesis	0.00	0.05
Evaluation	0.00	0.00

Classroom Observation and Test Evaluations

Teachers 1 through 5 were using a traditional textbook whereas teachers 6 and 7 were using a standards-based textbook. The mean number of questions posed per observation for each teacher is displayed in Table 3. The mean number of questions posed per assessment for each teacher is displayed in Table 4.

Tables 5 and 6 display the mean proportion of questions posed during observations and on representative assessments, respectively.

Table 3: Mean Number of Questions Per Observation

Teacher	Questions
1	32
2	24
3	23.4
4	29.6
5	34
6	20
7	17

Table 7 displays the overall mean proportion of questions posed at each level during observations and on assessments.

Table 4: Mean Number of Questions Per Assessment

Teacher	Questions
1	25.5
2	27
3	23
4	24
5	5.5
6	17
7	10

Discussion

Table 1 conveys a clear distinction between the levels of questions posed in a CPMP series textbook versus those

Table 5: Mean Proportion of Questions Posed During Observations

Teacher/Question	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1	0.47	0.25	0.16	0.13	0	0
2	1	0	0	0	0	0
3	1	0	0	0	0	0
4	0.86	0.07	0.03	0.03	0	0
5	1	0	0	0	0	0
6	0.60	0.20	0.05	0.15	0	0
7	0.21	0.41	0.15	0.12	0.06	0.06

Table 6: Mean Proportion of Questions Posed on Representative Assessments

Teacher/Question	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1	0.65	0.16	0.08	0.06	0.02	0.04
2	0.96	0.04	0	0	0	0
3	1	0	0	0	0	0
4	0.94	0.06	0	0	0	0
5	1	0	0	0	0	0
6	0.44	0.41	0	0.12	0.03	0
7	0.45	0.20	0.05	0.25	0	0.05

Table 7: Overall Mean Proportion of Questions Posed

Teacher/Question	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1	0.55	0.21	0.12	0.10	0.01	0.02
2	0.98	0.02	0.00	0.00	0.00	0.00
3	1.00	0.00	0.00	0.00	0.00	0.00
4	0.90	0.07	0.02	0.02	0.00	0.00
5	1.00	0.00	0.00	0.00	0.00	0.00
6	0.53	0.30	0.04	0.02	0.01	0.00
7	0.30	0.33	0.11	0.06	0.04	0.06

posed in a traditional textbook. The traditional textbooks examined for this particular study displayed a trend that as the level of question went up, the frequency with which a question was posed at that level went down. Although the same trend can be seen with the CPMP series textbook, it is far more gradual.

The traditional methods associated with mathematics teaching involve the instructor demonstrating how to perform a certain task (Senk, 2003). These methods are mirrored by the traditional textbooks in their format of showing examples for the majority of problems students will encounter (Cai, 2003). As you can see from the results of this study, there were 32 worked-out examples in the traditional text, and not a single worked-out example in the CPMP series textbook. In a traditional text, students often must simply work individually to replicate what was performed by their teacher or the text in order to be successful.

As discussed in the introduction, one of the primary goals of the NSF-funded project was to improve the quality of learning and teaching of mathematics (NSF, 1991). According to Cai, the problems posed in standards-based curricular materials are constructed in such a way that they aid in the development of students' higher-order thinking skills (2003). Teachers can encourage higher levels of thinking by asking questions that stimulate thought (Cooney, 1975). Techniques can be implemented to stimulate students' thinking by posing questions at different cognitive levels (Beamon, 1997; Brahier, 2000). Teachers have different styles and strategies for developing students' higher-order thinking skills, but effective teachers know how to ask questions (NCTM, 2000). It must be noted that this study did not explore the level of student learning that takes place in the classroom. Simply because higher levels of questions are posed, does not imply students develop higher levels of thinking. However, students will only respond to a question to the depth at which it is posed.

Examining Tables 4 and 5 one can see that standards-based curricular materials may increase the levels of questions posed in the classroom and on assessments. The largest differences can be seen in the knowledge, comprehension, and analysis. The frequency with which application questions were asked was comparable in both courses and on assessments.

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An interesting observation can be made by further examining the individual breakdown of questions for each teacher. One traditional teacher (Teacher 1) stands out from the rest. The number of questions posed in each category was very different from the other four traditional courses. The textbook may not be the only factor in determining the levels of questions posed in a particular classroom.

What is it about this particular teacher that influences the questions posed to students? One may think that this teacher has more experience than the other traditional teachers. However, Teacher 1 is the most junior of the traditional course teachers with 5 years experience. The other four teachers have a mean number of 14.25 years experience. This teacher is currently working on a master's degree in mathematics education, whereas the remaining four traditional course teachers have not taken a mathematics education course in a mean number of 15.25 years. Those who have pursued graduate degrees have focused their studies on school administration and supervision. One other distinct difference is that of all the teachers involved in this study, only Teacher 1 is a member of any professional organization. It is difficult to pin down the one factor that distinguishes this teacher from the rest. The difficulty may be due to the fact that there is not just one factor that guides teaching practice.

Implications

In general, it appears as though there are more high-level questions posed in a CPMP course versus a traditional course. The increased frequency with which higher levels of questions are posed seems to spread from the textbook to the classroom and to the assessment measures used. However, there are several concerns that still exist in relation to what transpired in the classrooms involved in this study.

One thing that must be mentioned is that although the CPMP textbooks seem to pose higher levels of questions, the actions of the teacher truly determine the level of a question. This study simply examined the question that was posed and did not explore the actions of the teacher in responding to students. One CPMP teacher, Teacher 6, would answer the questions for the students without allowing them to struggle with the problem at hand. Even further concern arose when one student asked what types of questions would appear on an upcoming assessment. Teacher 6 responded by informing the students of what specific examples provided in the notes would appear verbatim on the test. These actions confirm that although a textbook is used which inspires teachers to ask higher levels of questions, it is up to the teacher to implement the textbook in an appropriate manner. National and international efforts may be better spent on providing professional development programs focused on the importance of questioning techniques.

An important implication from this study can be seen in the actions of Teacher 1. Clearly what transpired in the classroom of this teacher did not depend on the textbook in use. This particular teacher made sure that everyone responded to questions and called on students at random (selecting names at random from a stack of index cards). The teacher also provided ample time for the students to think about their answers before moving onto another student for a response. There are exceptional teachers in school systems that will succeed no matter what type of textbook they use.

The analysis of the data resulting from this study results in more of an introduction to a new study than a conclusion. As with most studies, more questions have arisen during the course of the study than could have been imagined. There are several questions that could extend this study in the future.

(1) How have national and international efforts to create standards and curriculum documents influenced the types of questions posed in textbooks? What impact do these efforts have on the types of questions teachers pose in the classroom and on assessments?

(2) What teacher variables influence the activities in the classroom the most? Namely, what qualities do successful mathematics teachers, like Teacher 1, possess which relate to better methods of instruction?

(3) Do students in a course that utilizes a textbook based on the national and international reform efforts actually develop higher-levels of thinking versus students in a traditional course as a result of the increased frequency with which questions are posed at higher levels?

Conclusion

Textbooks may be seen as the driving force for what types of questions are posed in the classroom. Since the United States does not have a national curriculum, the effort to transform textbooks at a national level may have a tremendous impact on the way mathematics is taught. More specifically, it may have an impact on the types of questions posed in the classroom. However, textbooks are clearly not the sole factor in determining what transpires in the classroom. Other national and international organizations may come together in an attempt to create a set of standards and expectations for students to become successful. In order for those efforts to have a more profound impact on what truly takes place in the classroom, professional development programs should be created to help teachers increase the depth of questions posed in the classroom. Additionally, further research should be conducted on what variables influence the levels of questions posed in a classroom. If research can shed some light on this issue, then the international mathematics education community can learn how similar collaborative efforts at the national and international level will help teachers make strides toward increasing the levels of questions posed in all mathematics classrooms.

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