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College mathematics classroom for pre-service teachers: developing students' ability of communication that promotes deeper learning

S. Liang

Department of Mathematics, CSUSB, California State University at San Bernardino, United States.

*Corresponding author; Department of Mathematics, CSUSB, California State University at San Bernardino, United States.

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ABSTRACT

This paper reported the result of an innovative teaching project in pre-service teacher mathematics classrooms. The purpose is to share my experience of building a classroom environment of effective communication that not only promotes deeper learning but also helps students become independent thinker and learner. Some teaching strategies are discussed.

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1. Introduction

The National Council of Teachers of Mathematics (NCTM) in the Principles and Standards for School Mathematics (2000) had stated that communication is an essential part of mathematics teaching and learning. Effective mathematical communication is crucial because it is not only beneficial for students to reach deep understanding but also it is a vital skill for students to master in mathematics classroom (Chazan & Ball, 1999; Hirschfeld-Cotton, 2008; National Research Council, 1999; Wichelt, 2009). Communication can also strengthen students' mathematical thinking skills and stimulate high order of thinking (Artzt & Armour-Thomas, 1992; Artzt, Armour-Thomas, & Curcio, 2008). Researchers have reached a consensus that one of the characteristics for an effective mathematics classroom is that students are able to communicate their mathematics ideas effectively in oral or written. However, effective communication in mathematics classroom is not yet the norm of classroom teaching in the United States (Ball, 1991; Clark, Jacobs, Pittman, & Borko, 2005; Stigler & Hiebert, 1999). According to the TIMSS 1999 Video Study, most of the students in the classes of this study said fewer than 5 words during the class time (Hiebert et al., 2003). There is no research evidently showing that this norm has changed for the better until recent.

Having taught college mathematics for years, I have noticed that many students learn mathematics by rote. They memorized the rules and the procedure without understanding the underlying mathematical meanings. In traditional classrooms, teachers clearly demonstrate each procedure step by step, they repeat the steps when answering students' questions, and provide sufficient opportunities for students to practice procedures (Smith 1996). Students may be able to write the procedure by memorization but fail to know the reasons why the procedures work the ways they do. As a result, for many students mathematical knowledge is just like a huge pile of isolated puzzle pieces randomly put together and they can't see the connections among these pieces. Teaching procedures does not help students connect the puzzle pieces together. It is not surprising that students have difficulties to communicate effectively either orally or in writing in mathematics classroom. Often heard the comment from students is that "I know how to do it, but I don't know how to explain." This phenomenon also happens for the students who will be teachers in the future.

In their study, Seaman and Szydik (2007) found that many preservice elementary teachers don't understand fundamental mathematical ideas and lack the ability to make connections among those ideas. As mathematics teacher educators, we face the challenge of preparing our future teachers to practice effective teaching when they become teachers. Cobb, Wood and Yackel (1994) argued that teachers need to help their students learn how to communicate mathematics effectively. They reasoned that communicating mathematics ideas in oral and writing was not always considered important in mathematics classroom instructions because mathematics is so often involved in symbols and talking about mathematics is not necessarily natural for students. Consequently, it is necessary for teachers to provide students the opportunities to develop these skills. By offering them a variety of opportunities to conduct meaningful discussions in pairs, small groups, or whole class and work on worthwhile mathematical tasks, we can help them be able to communicate their mathematical ideas effectively. In the meantime, better understanding and deeper learning would take place, and communication skills would have been improved as well.

2. The innovative teaching project

Funded by the Teaching Resource Center of our university in 2011, I conducted a course development project that was designed to significantly change the traditional way (lecturing) of teaching Math 301A (the first course of Mathematics for Future Teachers). The goal of the project was to deeply engage students in communicating their mathematics ideas through multiple approaches (National Research Council, 1999) including:

- Engaging students in learning through group discussions and whole-class discussions.
- Asking students to conduct Individual and group presentations by writing their solutions or mathematics ideas on the blackboard and explaining to their peers.
- Having students to create word problems and provide the solutions with reasoning.
- Asking students to use different ways to solve a problem.
- Requiring students orally summarizing/reflecting what they had learned at the end of each class.
- Requiring students writing detailed reasoning for the answers in the quizzes or exams.
- Having students write a lesson plan (extra credits).

The class was structured in such a way so that the teacher minimized her lecture time to give the floor to the students, and students were the ones who talked or wrote their mathematics ideas most of the class time. Students formed small groups (3-4 students each group), usually each group conducted class activities together at first and then reported their results orally or in writing on the blackboard; the whole class discussion followed, that included comparing the solutions, questioning, reasoning, sharing thinking process, making critiques on other groups' work, and discussing if one solution is better than another. In addition, outside the classroom, Blackboard was utilized to build a virtual learning platform for students to share ideas.

3. Results

This course development project has been implemented in three classes in winter 2012 (27 students enrolled in the class) and spring 2012 (30 students in one section and 24 students in another section). The total enrollment in the three classes was 81. Both the department end-class survey and the teaching evaluations from the three

classes (scored 5.3, 5.4, and 5.3 out of 6) reflected a positive outcome of learning. Analysis of the department end-class surveys revealed that students' learning gains include:

- Growth of Students' ability of mathematical reasoning
- Development of Students' ability of constructing viable arguments and critique the reasoning of others
- Use of multiple approaches to solve problems.
- Learning with deeper understanding

63 students responded the end-class survey, on a scale from 0 to 5 (0 = not applicable, 1 = very little ..., 5 = very much), 79% (50 out of 63) of the students rated 4 or 5 for their growth in reasoning abstractly and quantitatively and 17% (11 out of 63) rated 3 for this same item; 73% (46 out of 63) students rated 4 or 5 for their growth in constructing viable arguments and critique the reasoning of others and 17% (11 out of 63) rated 3 for this item. For the question "in what areas have you grown the most", 56% (35 out of 63) of the students stated that they had become better for explaining mathematical concepts and ideas. For example, one student commented: "I learned how to explain rather than just do the problems"; another comments went, "It was good that it taught me how to explain math. I learned how to explain math to kids. I have a better understanding on fractions and how to teach them better"; interestingly, a student reflected, "I have the rules of math memorized so I never gave any thought to [the] meaning or reasoning until this class".

In responding the question "In what ways has this course enhanced your ability to teach mathematics", 65% of the students appreciated learning how to use multiple ways to solve a problem. A student realized that this course enhanced his/her ability to teach mathematics by teaching a concept in multiple ways including use of visual representations (graphs or pictures), manipulatives, or mental calculation. A response was expressed in this way: "This class has helped me see other views on a math problem". Another student said that "I have learned and have better understand concepts that I did not completely understand [before]. Also I have learned many different ways I can teach [to solve] the problems."

Based on the department survey and the teaching evaluations comments, students found that they had better understanding of some mathematical concepts than before. For example, 23 students claimed that fraction was the area they had grown the most; 10 students said that their ability of solving word problems had grown the most; some other areas listed as grown the most were decimals, division, multiplication, order of operations. Several students indicated that they had grown in all the area discussed in the course because they began with a very weak mathematics background. Two students mentioned that they gained confidence in their ability to teach mathematics. Students' performance in classroom or in the exams did reflected their self-report. As a teacher, I found a noticeable change that in class students asked more thoughtful questions and became better and better in explaining and providing appropriate reasons (in oral or written) to validate their solutions; in tests they tried hard to justify every step they did using mathematical reasoning. Some samples of students' work collected from the classes are included in the appendix.

4. Discussion

How our students teach in the future will reflect how we are teaching them now. When we teach pre-service teachers, we are modeling a norm of teaching. From grades K to 12, majority of our students had learned mathematics passively by listening and memorizing what teachers told them. They had not been provided opportunities to think deeply about mathematics concepts. Consequently, when they are given the chances to engage thinking and learning actively, they do not know how and some of them even resist doing that, because they were used to being told what to do during class time when learning mathematics and have formed the mindset that it is a teacher's responsibility to talk most of class time and judge if a student's answer is right or wrong. They don't feel comfortable to talk about what they are thinking in class because they are afraid of making mistakes. Reflecting on teaching the three classes, I would like to propose the following framework to promote learning with deeper understanding in pre-service teachers' mathematics classroom:

1. Establish a classroom culture that describes as follow
 - Friendly atmosphere
 - Everyone participates
 - Valuing every member's ideas
 - Not afraid of making mistakes

- Helping each other to learn
 - Collaborating
 - Grow together as a community
2. Design and implement content-rich and coherent lesson plans that are characterized as
 - goal-oriented
 - content-focused
 - interrelated content: connecting previous learning to the current exploration
 - facilitating progressive learning
 - having a sequence of “worthwhile” tasks organized in the order from simplicity to sophistication
 - providing challenging problems for students to solve
 3. Ask questions that stimulate students’ reflective thinking. For example,
 - Why do you think that would work?
 - Tell us more about your thinking
 - How did you decide that?
 - Can you justify your answer?
 - What make you think of that?
 - Can you explain why you think that is wrong?
 4. Provide opportunities for students to reflect on what have learned at the end of each class by asking
 - What did you learn?
 - What still puzzle you?

Establishing a classroom culture that fosters learning is a necessary condition for students to develop ability of effective communication that promotes deeper learning, but this condition alone is not sufficient to make learning with deeper understanding take place. All of these - Designing and implementing content-rich and coherent lesson plans, asking questions of motivating reflective thinking, and providing opportunities for students to reflect on each class, work together with learning-fostering classroom culture to make deep learning happen. Even though a class has a good learning environment, every student participates actively and communicates effectively, deeper learning would still not be reached without applying content-rich and coherent lesson plans. Class activities must be structured to motivate students to practice high order of thinking and build up their ability of applying learned knowledge to solve new situated problems.

5. Final remarks

Educational researches consensually indicate that mathematics teaching is a complex matter, involving numerous factors. It has been always the daunting task for mathematics educators to explicitly identify the cause and effect relationship between the factors and the learning outcomes. Subsequently, there are uncertainty and misconceptions of learning theories and pedagogies, that would prevent authentic effective teaching and learning from happening. In order to attain ultimate learning outcomes, as educators we must recognize that teachers can’t transfer knowledge to students but create variety of opportunities for students to construct their own knowledge through a progressive process. Although it is not easy task for decide what we should do in classroom and how we can reach our students to achieve deeper learning, the good thing is that we don’t need to work solely to deal with these complex problems alone. Sharing and collaboration would equip us with collective wisdom and strong intellectual power to find good solutions for the complex problem of teaching and constantly improve them for the better.

Hopefully this paper will stimulate questions and discussions about effective ways of building up students’ effective communicating skills and make deeper learning take place in mathematics classrooms.

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