A Snapshot of Ten Pre-Service Secondary Mathematics Teachers

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Abstract

Reform in secondary mathematics education has created changes regarding how to educate teachers. It is time to check the result of such changes. This study provides a snapshot look at the commonalities of ten pre-service teachers in regards to their mathematics knowledge and their attitudes about mathematics and mathematics education. Four themes emerged. The pre-service secondary mathematics teacher enjoys and has knowledge of secondary mathematics; does not enjoy nor have a deep understanding of undergraduate mathematics; is drawn to teaching and not overly drawn to mathematics; and has a medium-level of commitment to the National Council of Teachers of Mathematics.

Introduction

Technological and educational research advances and the vast body of work by the National Council of Teachers of Mathematics (NCTM) and mathematics educators which has produced, among other documents, *Curriculum Evaluation Standards for School Mathematics* (NCTM, 1989) and *Principles and Standards for School Mathematics* (NCTM, 2000) have drastically changed the perceptions of how pre-service secondary mathematics teachers ought to be educated (Roth-McDuffie, McGinnis, & Graeber, 2000). Based on the idea that teachers teach as they have been taught (Brown & Borko, 1992), many researchers are attempting to answer the question of what mathematical and pedagogical experiences pre-service secondary mathematics teachers should receive (e.g., Ball, 1990a, 1990b; Graeber, 1999; Graham & Fennell, 2001; Kinach, 2002; Quinn, 1998; Zazkis, 1999).

Much of this research is based on the idea that secondary mathematics teachers must have content knowledge, pedagogical knowledge, and pedagogical-content knowledge (Cooney, 1999; Even & Tirosh, 1995; Lappan & Theule-Lubienski, 1994). Pedagogical-content knowledge was originally discussed by Shulman (1986a, 1986b) and seems to concern itself with the transformation of subject matter knowledge into knowledge that will serve in teaching (Bromme, 1994; Kinach, 2002). Or, as Ball and Bass (2000) state, "Pedagogical-content knowledge is a special form of knowledge that bundles mathematics knowledge with knowledge of the learner, learning, and pedagogy" (p. 88).

In addition to content knowledge, pedagogical knowledge, and pedagogical-content knowledge, pre-service teachers hold sets of beliefs, including self-efficacy beliefs, and attitudes that influence their future success as teachers (Borko & Putnam, 1995; Cooney, Shealy, & Arvold, 1998; Enochs, Smith, & Huinker, 1999; Stuart & Thurlow, 2000). It is possible that pre-service secondary mathematics teachers actually have negative attitudes toward mathematics and that pre-service programs need to work to change these attitudes (Philippou & Christou, 1998). Pre-service teachers' view of mathematics may impede their ability to teach reform mathematics (Ball, 1996; Taylor, 2002). In addition, pre-service teachers might have views of teaching that are inconsistent with NCTM-oriented mathematics curricula (Wilson & Ball, 1996) and/or views

of teaching that are inconsistent with their views of mathematics (Camacho, Socas, & Hernandez, 1998). Some researchers believe that pre-service teachers have understandings that allow them to teach traditional mathematics but are not deep enough to teach NCTM-oriented mathematics (Frykholm, 2000; Kinach, 2002).

A large set of subquestions developed within the broader question of what experiences pre-service secondary mathematics teachers should have. For example, how do pre-service teachers view technology and how might a mathematics methods course influence those views (Quinn, 1998)? What type of mathematics content should pre-service teachers experience (Zazkis, 1999)? What can be done to develop pre-service teachers' pedagogical content knowledge (Kinach, 2002)?

Thus, researchers and educators have been designing teacher preparation programs that are attempting to address these and other questions (Camacho, Socas, & Hernandez, 1998; Roth-McDuffie, McGinnis, & Graeber, 2000; Taylor, 2002). Mathematics content courses are coming into alignment with mathematics methods courses, at least at some undergraduate institutions. These new pre-service programs, combined with the fact that some of the current pre-service teachers are products of NCTM-oriented mathematics education when they were K-12 students, are calling for yet another set of research. Are pre-service programs really changed, and/or have pre-service secondary mathematics teachers changed?

In 2000, a study gave evidence that the current pre-service programs were very similar to the pre-service programs in 1995 (Graham, Li, & Curan Buck, 2000). As of this writing, over half a decade beyond the 2000 Standards, what is the state of pre-service secondary mathematics teachers? Questions include the following. What are their beliefs about mathematics? What are their beliefs about mathematics teaching? What are their beliefs about students? What is their mathematics knowledge? What is their pedagogical knowledge? What is their pedagogical-content knowledge?

This paper does not contribute directly to the growing body of research on how pre-service teachers are to be educated, nor does it aim to give the results of a particular pre-service education program. Rather, it aims to contribute indirectly by offering a snapshot of ten pre-service teachers. It attempts to contribute toward an answer to the question: What is the state of pre-service secondary mathematics teachers? Thus, this paper attempts not to address "what should be?" but rather, "what is?" The author is grateful to the reviewer for providing many helpful suggestions and pointing out several relevant references.

Subjects

The subjects were ten students enrolled in an undergraduate mathematics course that the author teaches, entitled Foundations in Mathematics and Geometry (foundations), during the spring semester of 2005. The course is intended for secondary mathematics majors and serves as a bridge course into higher order mathematics. Thus, the typical student would have completed the calculus series and perhaps a statistics or discrete mathematics course, but not an analysis or abstract course. In addition, the typical student in foundations would also be taking some introductory mathematics education courses, such as the first in a series of required mathematics methods courses, but would not have student taught yet. In the introductory mathematics education courses, the students are exposed to the concepts of the NCTM and would have done some examining of NCTM's publications. Finally, even within the foundations course, some principles and/or ideas from NCTM are used, in an effort to have students experience NCTM concepts in a mathematics course. For example, some group work is used in the foundations

class, as well as an emphasis on communicating mathematics. Six of the subjects were male and the remaining four were female.

Method

Numerous artifacts were colleted for each subject. Of course, the subjects' scores and final letter grade in the course were available. In addition, each subject agreed to have the author examine his or her academic record, which included lettergrades in other mathematics courses.

The subjects were asked to participate in one-on-one interviews with the author. See Appendix 1 for the interview questions. The interview questions were created by the author. The author read the interview questions while the subject answered. The interviews were audiotaped and later were transcribed.

Subjects were asked to complete a survey. See Appendix 2 for the survey. The survey was formed by selecting items from the 2000 National Survey of Science and Mathematics Education (copyright held by Horizon Research Inc.), as well as some author created items. Note that this study would be much weaker if only this survey were used. For example, one item states, "I will require students to explain their reasoning when giving an answer." Two people may be extremely similar in their philosophies and views of NCTM, and yet have one answer "almost always" and another "sometimes." That is, these two responses, although different, may mean about the same to two different people. However, most people would mean different things if responding "almost always" versus "almost never" and so if care is taken with the responses and combined with responses on other instruments, an argument of evidence might be accumulated.

Finally, the subjects were asked to take two mathematics tests. The first test was formed by taking items from standardized tests for testing mathematics at the high school level. The test consisted of 30 multiple-choice items. The first 15 were taken from the mathematics test (Test Q) of the Iowa Test of Educational Development (ITED). These items represent the content and processes given in bold in Table 1.

The 15 items are based on realistic situations. The ITED is a well-respected high school achievement battery, with high quality of reliability and validity. However, the ITED is not intended to be used on pre-service teachers. Thus, the reliability and validity evidence does not necessarily transfer. Nevertheless, the items are quality items that test high school mathematics. The items are not inconsistent with NCTM standards, but ITED is not necessarily intended as a NCTM-oriented high school test.

The remaining items were taken from New Standards. New Standards is intended to be consistent with NCTM standards. The mathematics test consists of three parts, most of which are open ended. However, the items chosen were from the multiple-choice items. The items chosen from the test measure mathematics skills and concepts. Skills assess students' ability to use mathematical procedures and computation. Concepts assess students' ability to apply a mathematical concept to a practical situation. Returning to Table 1, the reader will find the breakdown of items according to content and process from New Standards shown in italics.

Because the items are from actual standardized tests, it is inappropriate to reproduce the actual items in this paper. The reader is reminded that these tests are appropriate to measure the mathematics skills and concepts of secondary students both in a fairly traditional (ITED) and more reform (New Standards) method. The test should produce a measure of whether pre-service teachers can do secondary mathematics problems.

Table 1

Process/Content breakdown. Bolded entries are from the ITED. Italicized items are from New Standards.

Process Content	Skills	Interpret Information	Set up a 1-process problem	Solve a 1-process problem	Set up a 2-process problem	Solve a 2-process problem
Whole Numbers Exponents			**1 Item**	**3 Items**	**1 Item**	**2 Items**
Fractions Decimals Percents Ratios				**1 Item**		**1 Item**
Geometry Measurement Estimation Rounding		**1 Item**	**1 Item**	**1 Item** *1 Item*		*2 Items*
Statistics Probability			**1 Item**	**1 Item**		*3 Items*
Functions Algebra	*2 Items*			*1 Item*		
Tables Graphs		**1 Item** *1 Item*		*1 Item*		*4 Items*

The second test was an intact mathematics test from the ACT (a released practice test was used). This is a 60-question multiple-choice test designed to measure the mathematical skills normally acquired by students in typical mathematics courses taken through the eleventh grade. Basic formulas are not provided, and some computational skills are required. The material comes from pre-algebra/elementary algebra (24 questions), intermediate algebra/coordinate geometry (18 questions), and plane geometry/trigonometry (18 questions). The items on the ACT are of a higher level than those on either ITED or New Standards. The test should produce a measure of whether pre-service teachers have the needed skills to fully understand undergraduate mathematics.

The data were scored using the constant comparison method (Gay & Airasian, 2000). This method involves reading the responses to determine the core, distinctive characteristics that exist and then putting them into appropriate categories or themes. The author constantly compared new responses to older responses and asked whether the response fits into an existing category. Initial categories were then narrowed by looking for support via triangulation using the four different instruments as the data sources. Furthermore, the author used negative case and discrepant data methods to eliminate or refine the final categories (Gay & Airasian, 2000).

A final artifact involved a different set of subjects. During the semester that the author taught the course, the author emailed all mathematics majors at the university who were not also mathematics teaching majors and simply asked them to respond with an email that answered this question: Why did you choose not to be a math teaching major?

Results

The reader was promised a snapshot view of these 10 pre-service secondary mathematics teachers. Although no claim is made toward generalization of results, it is the author's desire to give a snapshot of a "typical" specimen. Thus, the results are given as a listing of themes or commonalities.

Theme 1: The pre-service secondary mathematics teacher enjoys and has knowledge of secondary mathematics.

Pre-service secondary mathematics teachers have the mathematics knowledge and skills that are required to accurately perform secondary-level mathematics. The survey results paint a picture of a teacher that feels that he understands content knowledge in mathematics (8 agreeing that "My content knowledge in mathematics is strong", and 2 strongly agreeing with the statement), with a few even believing that their own knowledge is superior to fellow majors. Of course, feelings are not always accurate. Yet, the results on the first test, which was a mixture of problems from the ITED and New Standards, were 90% and above.

In the interview, when asked what one likes best about mathematics, the pre-service teacher mentioned elements of mathematics present in secondary mathematics and/or in the learning of secondary mathematics. Consider these quotes.

- The best part is being able to go through the manipulation and the best part about that is the end when you have the answer and you are like, 'I did all this right. There I go!'
- I really like computations in which you just plug in and get an answer out!
- I like being given an algorithm to follow. I am good at mastering algorithms. The best part of mathematics is when it [the algorithm] clicks.

Further, no pre-service teacher mentioned mathematics from a higher level.

Theme 2: The pre-service secondary mathematics teacher does not enjoy nor have a deep understanding of undergraduate mathematics.

Although the pre-service teacher has knowledge of secondary mathematics, evidence points to pre-service teachers not having as deep of an understanding of undergraduate mathematics as others have, such as mathematics majors. The lettergrades of this group of ten pre-service teachers in undergraduate mathematics courses were predominately Bs, with a few As and a few Cs. In comparison to mathematics majors who were not also teaching mathematics majors, there were many more As and almost no Cs. In addition, the pre-service teachers did not feel qualified to teach more advanced topics, such as those from abstract algebra. (Since the mathematics majors have no intention of teaching, it is not easy to make a comparison with their comfort level at teaching abstract algebra, but no claim is made that they would be comfortable either!)

When asked during the interview what one likes least about mathematics, the pre-service teachers showed their dislike of undergraduate mathematics, and their feeling that it was difficult. Consider each of the following examples:

- I like proofs least. I have a tendency, as long as I got the right answer, I didn't care why it was true.
- I guess what I don't like is all the symbols.
- I don't like abstract math. Those crazy proofs that we had to do. I didn't understand it at all.

Proofs, symbols, and abstract mathematics are a major part of undergraduate mathematics, and it seems strange that future mathematics teachers would dislike them. One pre-service teacher

emphasized that she would not be able to be a pure mathematics major. She says that her family would prefer that she drop the teaching part of the major and just major in mathematics, but she says, “They don’t get it though. They don’t get how hard it is for me.”

The results from the second test, an intact ACT mathematics exam, ranged from 66% to 97%, with most scores in the 70-79 percent range. Although this material is intended by ACT to be on mathematics that is normally covered by the end of eleventh grade, the test is intended to test those skills needed for college. Thus, the test does not directly measure undergraduate mathematics ability, but does often serve as a placement test into college mathematics. Note also that these students have taken this test after having taken several undergraduate mathematics courses, which should only have raised their scores, if one accepts that the skills tested are needed and used in undergraduate mathematics courses. It seems fair, then, to use the scores on this test as some evidence that pre-service teachers might not have a deep understanding of undergraduate mathematics, as they do not have a deep understanding of incoming skills needed for undergraduate mathematics.

Theme 3: The pre-service secondary mathematics teacher is drawn to teaching and not overly drawn to mathematics.

The pre-service teacher has a commitment to teaching over having a commitment to mathematics. When asked during the interview if the pre-service teacher could not be a mathematics teacher, what was his or her second career choice, all ten replied that it would be to be some other type of teacher. Here are some representative quotes.

- I probably would be a teacher of something else. I really want to work with high school age students. I don’t like the very impersonal things in math. The interaction with people is important.
- I would be a teacher of some other subject. You know, I like math. But, I’m not a fanatic. I don’t really get into it the way a lot of people get into it. I think in teaching you have to draw on a lot of different talents in order to do it. The best math teacher can really be a great teacher and not know all his math. But, there is something that students can relate to. I hope I can find that.
- I’d be a teacher of some other subject. I’m not really that interested in math.

Contrast the response of the pre-service teachers to the response of mathematics majors who were not teaching majors, when asked why they were not mathematics teaching majors. The top reason given was that the teaching math field does not allow for enough use of mathematics, or at least for enough use of higher-level mathematics. Thus, their love was for mathematics before teaching.

Returning to our pre-service teachers, all ten of the pre-service teachers responded during the interview that they would be happy if they ended up being a secondary mathematics teacher all their life.

- I feel like I have a calling.
- My mom taught for 34 years all in the same school. And I know she thinks she has had a great life. And if I could be in her position, when I am her age, I would be really happy.
- I’m at the point where I can’t wait to start.

Yet, there is an inconsistency in this theme. When pre-service teachers were asked in the interview what they liked best about mathematics, the pre-service teachers mentioned the satisfaction of solving problems. Certainly, solving problems is a big part of mathematics, and

this does reveal some love of the topic. Later in the interview when asked what one likes best about teaching, they answered that it was seeing others enjoy this same satisfaction of successfully solving problems.

- Probably the biggest thing is when they understand it suddenly, and then they do well, and then they are so happy about it.
- Teaching someone else is like, 'oh my gosh, I did it.' And they did do it! And that look on their face is just … Ah ha moments… when the light bulb goes on and it is a great moment to see.

Such quotes prompt the question: Is it possible that pre-service teachers do like mathematics more than they realize? Still, the following quote is representative of the view of the pre-service teachers that mathematics is just a part of their future jobs.

- You are getting paid to educate these kids. But, there is so much more than just math. The way I view it, I sure hope I can keep it going, you are educating the whole person. It breaks down to even what you wear when you show up for class. The way that you speak. The examples that you use. There is so much more than just teaching how to manipulate the numbers.

Theme 4: The pre-service secondary mathematics teacher has a medium-level of commitment to NCTM Standards.

In the survey, 8 out of 10 pre-service teachers responded "*sometimes*" to the statement "My teaching will be in alignment with the NCTM" (other choices were *almost never, no opinion, often,* and *almost all the time*). Other items that were in alignment with NCTM also received medium support. For example, consider Table 2, and, in particular, the pre-service teachers did not show a strong commitment either to requiring students to explain their reasoning or to requiring students to find more than one solution path. In addition, pre-service teachers commitment to calculators is not strong (with 8 pre-service teachers responding that they will have students use calculators *sometimes*, while *often* and *almost all the time* were choices). To the statement, "I believe that the NCTM is correct about their philosophy and standards", one subject strongly disagreed, two disagreed, two agreed, and five held no opinion on this statement.

Some quotes are given below.

- I really don't like NCTM. I don't want to teach it. I don't want to teach it that way. If I can't find a way to teach traditional math… well, then I will go to college, get a masters, and teach traditional math at a community college.
- In traditional mathematics, you can come to a conclusion. I really like that. You know there is a right or a wrong.
- Before I learned about NCTM, I liked the fact that math has an answer to get to. And I'm learning that that is not apparently always the case.
- There are some benefits to NCTM, but I've noticed that you really have to supplement it a lot. And, anyway, why do we want to turn math courses into science courses? We already do lab work in science courses. It is very time-consuming and students have a hard time understanding what the exploration or investigation is even about.

The author has already acknowledged that there is weakness in the survey, however, if we combine the survey results with the quotes above, the theme is established quite strongly.

Table 2
Results from a portion of the survey

Pedagogical statements: **When I am a teacher,**	Almost never	Sometimes	No opinion	Often	Almost all the time
My teaching will be in alignment with the NCTM.		8	1	1	
I will require students to explain their reasoning when giving an answer.	1	5	1	2	1
I will require students to give more than one answer and/or more than one solution path.	5	4		1	
I will have students use calculators.	1	8			1
I will make use of group work.	1	7	1		1
I will emphasize that students must master basic facts and computations.		1		6	3
I will give an application for the math that I am teaching.		3		3	4

Also interesting is that on most mathematics topics, the pre-service teachers felt very well qualified to teach them. Exceptions to this, however, were found regarding more reform type topics, such as data collection and analysis, probability, statistics, and discrete mathematics. Thus, one might wonder if the pre-service teacher not only has a medium-level of commitment to NCTM Standards, but also a medium-level of ability to teach according to NCTM Standards.

Remarks

In this study, we have attempted to give a snapshot of our pre-service secondary mathematics teacher by finding the commonalities of the ten majors at our university during a given semester. The picture we have is of a pre-service teacher dedicated to teaching and secondary mathematics, not as dedicated to mathematics at the undergraduate level, and not completely dedicated to NCTM Standards. In contrast, the mathematics majors at the same university, the same semester, who were not also teaching mathematics majors, were very dedicated to undergraduate-level mathematics and did not want to be teachers because they found secondary-level mathematics to be too low of a level.

It seems, then, that this study calls for much further study in two main directions. First, this is a snapshot from one university, one semester. These ten pre-service teachers may or may not be typical of the author's own university, let alone other undergraduate institutions. Thus, clearly, replication studies are needed.

The second direction is to continue the line of work that examines what experiences pre-service secondary mathematics teachers need. It is not an acceptable situation, for example, if this attitude toward undergraduate level mathematics is consistent in pre-service teachers. In addition, it appears that further work needs to be done with pre-service teachers, if we want them to be fully supportive of NCTM. On the positive side, it appears that pre-service programs are succeeding in attracting and/or educating pre-service teachers with a great love for teaching.

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Appendix 1: The Interview Questions

1. Trace your academic life (put it in context with your life story).
2. How did you decide to become a secondary mathematics major?
3. Were there other majors you considered?
4. What do you like best about math?
5. What do you like least about math?
6. What do you like about teaching?
7. Is there anything you don't like about teaching?
8. If you couldn't be a math teacher, would you be some other kind of teacher, or something else with math, or neither?
9. Were you ever discouraged in this major, and, if so, what caused the discouragement?
10. Were you ever particularly happy as a secondary math major, and, if so, what caused that happiness?
11. In order to be motivated, do you need to see an application for the mathematics that you are studying?
12. What do your friends feel about mathematics?
13. Tell me about your parents' and siblings' reactions to you being a secondary math major. (Include what do the parents and siblings do for a living?)
14. Do you think you will be a secondary mathematics teacher all your life?

Appendix 2: Survey

Content Knowledge	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
My content knowledge in mathematics is strong.					
My content knowledge in mathematics is sufficient for teaching secondary mathematics.					
My content knowledge in mathematics is superior to most of my fellow students in the teaching secondary mathematics major.					
My content knowledge in mathematics is superior to most UMD mathematics majors.					
I expect that the college math courses I take will be helpful to me in teaching mathematics at the secondary level. (do not include Math 3110)					
I expect that the college math methods courses I take will be helpful to me in teaching mathematics at the secondary level. (do not include Math 3110)					

Within mathematics, many teachers feel better qualified to teach some topics than others. How well qualified do you feel to teach each of the following topics at the level of secondary mathematics.	Not well qualified	Adequately qualified	Very well qualified
Numeration and number theory			
Computation			
Estimation			
Measurement			
Pre-algebra			
Algebra			
Patterns and relationships			
Geometry and spatial sense			
Functions (including trig functions) and pre-calculus concepts			
Data collection and analysis			
Probability			
Statistics			
Topics from discrete mathematics			
Mathematical structures (e.g., vector spaces, groups, rings, fields)			
Calculus			
Technology (calculators, computers) in support of math			

Answer this question by circling yes or no: Regardless of whether you are or are not a double major in mathematics and teaching mathematics, is obtaining a double major something you are academically capable of doing? Yes No

For any course below that you have completed, please write in your letter grade received.

Course	Letter grade Received
Calculus I	
Calculus II	
DE with Linear Algebra	
Intermediate Analysis	
Discrete	
Abstract Algebra I	
Intro to Prob and Stat	
Linear Algebra	

Pedagogical statements: **When I am a teacher,**	Almost never	Sometimes	No opinion	Often	Almost all the time
My teaching will be in alignment with the NCTM.					
I will require students to explain their reasoning when giving an answer.					
I will require students to give more than one answer and/or more than one solution path.					
I will have students use calculators.					
I will make use of group work.					
I will emphasize that students must master basic facts and computations.					
I will give an application for the math that I am teaching.					

Philosophy Items:	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
I think it is important that all students are prepared for college.					
If I have to change what and how I teach in order to help students transition to college, I am willing to do so.					
I believe that the NCTM is correct about their philosophy and standards.					