

Assessing Teaching Practices of Secondary Mathematics Student Teachers: An Exploratory Cross Case Analysis of Voluntary Field Experiences¹

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Current reform efforts to improve the quality of mathematics teacher education include recommended changes in standards from multiple sources such as professional organizations (National Council for Teachers of Mathematics, NCTM, 2000;

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National Council for Accreditation of Teacher Education, NCATE, 2002). Moreover, researchers (von Glasserfeld, 1987; Glaser, 1988) note that recent reforms support a constructivist framework concerning assumptions about knowledge, learning, and teaching that promote students' deeper understandings of concepts and the relationships of concepts as opposed to memorization of isolated information. According to O'Brien and Korth (1991), learning outcomes are viewed as a result of the ways that students process and interact with information, leading to an interactive view of teaching. Interactive instruction engages students in problem solving, modeling, and constructively building conceptual understanding in student-centered classrooms. In

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addition, the standards advocate promoting excellence for all students irrespective of their gender, race, social, cultural and economic backgrounds (Kennedy, 1991). The kind of teaching supported by the standards requires a more active, inquiry-based process where students are at the center of instruction with the teacher as an organizer, challenger, and facilitator of student achievement (Bigelow, 1990). However, despite the general acceptance of a constructivist active learning approach to reforming teacher practices nationally, researchers have found that teaching practice continues to be viewed as knowledge transmission from teachers to students by telling followed by practice (Smith III, 1996).

To mitigate this outcome, the Pre-service Secondary Mathematics Teacher Education Program at Florida International University (FIU) was revised to incorporate the six principles from the National Council of Teachers of Mathematics (2000) shown in Table 1, emphasizing early field experiences with teachers who modeled constructivist teaching and learning. The curriculum approach provided opportunities for the pre-service teachers to experiment with abstract concepts, objects, and relationships, and pursue conceptual understandings (Jiang, McClintock, & O'Brien, 2003; Jiang, Manouchehri, & Enderson, 2002; McClintock & Jiang, 1997; Jiang & McClintock, 1997). In addition, modeling in mathematics is emphasized in the courses of the mathematics education program as recommended by Dossey, Giordano, McCrone, & Weir (2002). In the courses, the FIU faculty designed field experiences to help pre-service teachers understand the nature of teaching by observing and interacting with mentor teachers, reflect upon learning and teaching, and prepare for student teaching. Pre-service teachers were invited to participate in after class workshops that featured guest experts from other universities, schools, and/or professional associations on topics such as modeling, technology and learning, and integrating mathematics, science, and technology in the classroom.

Table 1
Six Principles to Define Quality Teaching and Learning of Mathematics

Equity: Excellence in mathematics education requires equally high expectations and strong support of all students.

Curriculum: A curriculum is more than a collection of activities; it must be coherent, focused on important mathematics, and well articulated across the grades.

Teaching: Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.

Learning: Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.

Assessment : Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.

Technology: Technology is essential in teaching and learning mathematics: it influences the mathematics that is taught and enhances students' learning .

Adapted from National Council for Teachers of Mathematics (2000).

Analyses of the impact of reform-based teaching practices in FIU's program have been previously reported (Jiang, O'Brien, & McClintock, 2003; Mendez, O'Brien, McClintock, & Jiang, 2003; Jiang, O'Brien, & McClintock, 2002). However, the impact of the field experiences *per se* has not been assessed. The purpose of this study was to determine if field experiences can change pre-service teachers' views about teaching from knowledge transmission to a more interactive constructivist perspective. The following question was posed: Do pre-service teachers with a significant amount of optional supplemental field experiences use reformed-based practices more compared to those who do not?

Method

The naturalistic paradigm (Moschkovich & Brenner, 2000; Erlandson, Harris, Skipper, & Allen, 1993) was used for the investigation. This paradigm combines the linear structure of the traditional research design (i.e., define the research question, design the study, collect the data, and analyze the data) with a more circular qualitative research process.

Participants

In the spring semester of 2003, seventeen pre-service mathematics teachers enrolled for student teaching. Classroom observations were conducted every week during the semester. Each student teacher was observed five times by the authors. Detailed field notes were taken for each observation. In addition to the observations, each student teacher agreed to be videotaped during three other class lessons. The purpose of the videotaping was to secure a record of the lessons for in-depth analysis (Lesh & Lehrer, 2000).

In depth case study analyses were conducted for a sample of four of the seventeen student teachers enrolled in the spring and summer of 2003: Lisa, Debbie, Victor, and Jay. [Note: Pseudonyms are used to protect their anonymity.] They had the highest GPAs and strongest academic mathematics backgrounds (considering the depth of mathematics courses completed and grades in these courses) of all the student teachers in the cohort. Two of the student teachers, Lisa and Victor, had participated in the voluntary experiences in the *Partnership in Academic Communities* (PAC) program during their junior and senior years. They were the only student teachers in the group of 17 with these extensive voluntary experiences. While Victor completed his student teacher internship in the PAC program, the other three participants completed their student teaching at local public schools. The student teachers were placed with the best available cooperating teachers during the semester. Because the four participants were similar in terms of their academic performance, the researchers focused on the possible differences among them due to the differences in their volunteer experiences.

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FIU's PAC Program

Faculty of FIU and Miami-Dade County Public Schools (MDCPS) established the Partnership in Academic Communities (PAC).² This program is housed on the FIU campus where about 120 at-risk students (in the 7th-12th grades) attend mathematics, science, and technology classes daily during the school year. Demographically, the group is comprised of 51.6% male (48.4% female), 65% Hispanics, 30% African Americans, 2% Caucasians, 1% Asians, and 2% multi-racial. The students attend one feeder pattern community of three middle schools and one senior high school. They spend one-half of each day at the University and the other half in the home school. University faculty, graduate students, and some of the pre-service secondary mathematics teachers work with six district teachers in providing the at-risk students with standards-based curriculum and instruction. Every semester, pre-service secondary mathematics teachers in their junior and senior semesters are assigned early field observations in the PAC program as part of their coursework. They spend approximately 15 hours per semester observing teachers who take advantage of technology and emphasize applications of mathematics and science with students.

Voluntary field experiences. Since 1998, approximately 7-10 percent of the pre-service teachers have volunteered to work more intimately and regularly with middle school and high school students and their teachers, sometimes as much as an extra 900 hours beyond their regularly scheduled course activities.³ Volunteers assumed the responsibility to co-teach classes as frequently as one day per week throughout an entire academic year; created lessons and projects; and worked with individual children and small groups. They incorporated the use of technology, modeling, and cooperative group work to develop and apply concepts and problem solving skills (Park, O'Brien, Eraso, & McClintock, 2002). They experienced and studied how a constructivist curriculum operates, noting the impact of reform-based teaching practices on the children's achievement and attitudes.

Data Sources and Analyses

Data from multiple sources were collected. The field notes related to the subjects were compiled for easy access. Their videotaped lessons were digitized and put on multiple copies of CDs that were analyzed independently by the three researchers. In addition, cooperating teachers' observational assessments of student teacher lessons were compiled for review.

A constant comparison approach (Glaser & Strauss, 1967) was used to analyze the data. This method of analysis is inductive where data is moved to tentative theory, to new data, to refined theory. The observational data (field notes and videotape analysis of teaching) were reviewed and compared with the interview data (notes and videotape analysis). During this process, commentaries were made when noteworthy parts or pieces were found. The researchers shared their commentaries and identified themes such as the student teachers' views of mathematics,

views of mathematics teaching, teaching style, and the consistency or inconsistency between professed views and teaching actions. As the data reviews and discussions continued, the researchers began writing the individual case studies, continuously revising as the accumulated data suggested new insights or naturalistic inferences. Based on all four individual case studies, an analysis across the four participants was conducted.

For each participant, the three lessons that were videotaped were analyzed by each of the three researchers. Six categories were derived from a review of literature (Lawrenz, Huffman, & Appeldoorn, 2002; Lawson et al., 2001; Sawada & Pilburn, 2000; Sawada et al., 2002) as well as the researchers' knowledge of the reform and standards-based components of FIU's Pre-service Secondary Mathematics Teacher Education Program. In addition, a seventh category was added based on the observations and interviews. The categories were: (1) using technology effectively, (2) solving non-routine problems, (3) doing mathematical modeling, (4) conducting student-centered activities, (5) teaching in an interactive form, (6) leading students to construct concepts, and (7) conducting teacher directed lesson segments.

Results

Results are reported in two ways. First, summary analyses are presented for each student teacher's teaching style (as derived from the combined data) and his or her conceptualizations of mathematics and mathematics teaching. Second, a cross-case comparison among the four student teachers is presented to show the similarities and differences.

Individual Case Analyses

A full presentation of each case study is beyond the scope of this article. For each student teacher, brief examples from the lesson observations are described to show teacher actions, and excerpts from interviews show teacher beliefs.

Lisa. Lisa (Hispanic white, excellent English and Spanish language proficiencies), in her early 20's, taught Algebra I and Algebra II during her student teaching. Lisa's supervising teacher was an experienced supervisor who permitted student teachers to vary from the typical textbook and classroom routine only when the lesson was quite carefully planned, and in her judgment, had a good chance of success. In her lessons, Lisa consistently engaged students in active explorations and investigations. One of Lisa's lessons explored the life expectancy of people living in different periods of time. Students used a spreadsheet to address the question: "*Is there a model that you can use to predict how long a person will live if he or she was born in a certain year?*" Life expectancy data in tabular form was provided for the learners who then manipulated the data to generate scatter plots and subsequently regression equations utilizing software on the desktop computers. They discussed the meaning of the coefficients in the regression equations and,

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based on their input, modifications were made to improve the predictive qualities of the equations. In this lesson, students used technology to derive the meaning from real-life data in multiple representations, dialogued with one another as they negotiated their knowledge to arrive at the final product, and analyzed the predictive value of the generated functions. They concluded with a discussion of the parameters of the functions that yielded valid predictions.

Lisa used mathematical concepts and processes naturally and quite correctly in all observed classes. *“In high school I always succeeded. Math came really easy to me. All of the college courses are fine. I did well in these courses . . . I think I’m pretty confident in teaching anything,”* she reported in her interview. When questioned about her preparation for student teaching, Lisa commented that working in the optional parts of her program, especially PAC, strengthened her views. She elaborated,

The PAC program has served as a great source of learning and development in my teaching career. Working in the PAC program with other teachers that share similar philosophies helped me solidify my own philosophical beliefs regarding pedagogy. . . . Thus, I came to realize that mathematics education is much different than it was years ago. It is no longer lecture-based with drill and practice exercises. I think it has become a much more esteemed profession that involves the integration of technology, science, real-world data and applications, and mathematical reasoning. This implies that teachers must be trained to be well-rounded and have a deeper understanding of mathematical concepts, not just surface knowledge.

Debbie. Debbie (non-Hispanic white, excellent English, but no Spanish language proficiency), in her 30’s, taught Algebra II during her student teaching. Debbie’s supervising teacher was the mathematics department chair at a large high school in a predominantly middle to low-middle socio-economic part of the city. She was a very traditional teacher, in that she used little problem solving, modeling or technology in her teaching. Similarly, Debbie’s lessons always began with a teacher-centered presentation followed by some questions for students to answer or some procedural tasks for students to follow. She expected the students to follow her instructions.

In one lesson on solving systems of linear equations, she began with a formal presentation of the substitution and addition/subtraction methods. After explaining the methods, she wrote a word problem on the board and asked the students to complete the steps in solving the problem. She repeated this approach with another word problem. Debbie did most of the talking. In a lesson on multiplying polynomials, Debbie began with a presentation of the concepts and how to multiply binomials, and then assigned polynomials for the students to multiply within small groups which helped students to visualize the abstractions of this skill. She used manipulative resources to support visual meaning. During her interview, Debbie expressed a preference for *the old fashioned way* of teaching: *“I’m probably somewhat strict. I don’t like a lot of chaos and a lot of talking because most often*

[during] that chaos and that talking they are not on task." She explained that while she liked the idea of student-centered teaching, she felt that it was difficult to implement given the time constraint of a 55-minute period that often became 40 minutes after dealing with housekeeping issues such as attendance and make up work. Debbie continued to explain why she was accustomed to teacher-centered instruction: *"For me it was a very hard transition, because I'm an older student and I've done it the old fashion way for my whole life until my last semester before internship. You know how people say, "it's hard to teach an old dog new tricks."*

Victor. Victor (Hispanic white, excellent English and Spanish language proficiencies), in his early 20's, taught pre-calculus and geometry as a student teacher. Victor's supervising teacher was a young teacher who used standards-based practices consistently in her classes, had an earned master's degree, and was very committed to her students. Victor's lessons were designed to engage the students, who were expected to participate actively. For instance, in a geometry class, he designed and implemented several consecutive lessons in which each student participated in a group to build a balsa wood bridge that would hold the most weight. They created drawings (using a software program) as well as models to plan and then build their bridges. They predicted what model they thought would work best and after much reflection and re-evaluation, they developed alternative plans and modes of investigation. As a result, the students created a rigorous learning environment for themselves as they challenged each other with further ideas and suggestions for improving the bridges. Victor described the impact of his PAC experience on his development as a future teacher:

Through the PAC program, I was able to be at a level between teacher and student. As a teaching assistant, I got [sic] the experience of working directly with students, answering their questions, helping them learn concepts, etc. On the other side, I got [sic] to see at first hand what teachers had to deal with outside of the classroom (grading papers, creating lesson plans, testing, classroom management, etc.). Being involved with the PAC program helped me to start shaping how I would want to manage and run a classroom. I saw examples of what worked and what failed with students in terms of teaching styles and classroom management. The PAC program helped me to improve my skills as a future educator and to apply little by little the reforms of the NCTM easier than other teachers in other schools that I was hearing about. My experience in PAC is something I will forever look back on and use as my base in forming my teaching philosophy.

Jay. Jay (Hispanic white, excellent English and Spanish language proficiencies), in his early 20's, was assigned to teach Algebra II during student teaching. Jay's supervising teacher was co-department chair at a high school of approximately 4500 students, about 90% of whom were from Hispanic families. Although he supported student teachers to use reform-based practices, he tended to be more traditional in his teaching. Jay's teaching practice did not focus on student explorations or accommodate different learning methods very well. Instead, Jay

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focused more on algorithms and symbolic manipulation. One of his lessons focused on simplifying radical expressions while another dealt with rationalizing the denominators of radical expressions. Both lessons started with Jay writing a problem on the board and solving it with some degree of student input. Jay emphasized relevant information, referenced pertinent algorithms, and solved additional problems in similar fashion. Jay then wrote a problem on the board and observed as the students solved the problem individually. Jay then asked a volunteer to solve the problem on the board as he evaluated the solution. The cycle was repeated with a slightly different problem. Moreover, Jay’s style of teaching only partially reflected his beliefs of how a mathematics class should ideally be taught. He spent much time in attempting to get algebra students to use definitions in the basic mathematical reasoning processes. He stated in his interview, “*I’ve grown to appreciate a more hands-on approach, a more discovery-based approach as opposed to non-stop on the wall dictating.*” In his own words, Jay structured a typical mathematics lesson as a review of background information needed, followed by exercises chosen from the textbook. For example, he mentioned *rational roots* as a difficult concept to teach with a hands-on approach. He explained, “*Math could be exciting...but hard to make exciting.*”

Cross-Case Analysis

The two student teachers with extensive volunteer experiences with PAC (Lisa and Victor) devoted higher percentages of time during their lessons to reformed-based practices, as shown in Table 2. The participants who had more volunteer experiences in PAC demonstrated qualitatively more standards-based, reform-oriented, student-centered practices than those student teachers (Debbie and Jay) who did not have such extensive experience. Differences among the student teachers were revealed for how to design and implement a lesson, how to engage and interact with students, how to

Table 2
Average Percent Time for Each Category of Instruction for All Lessons

Category	Summary Across All Three Lessons for Each Student Teacher			
	Lisa’s %	Debbie’s %	Victor’s %	Jay’s %
1. Using Technology Effectively	40	0	25	0
2. Solving Non-Routine Problems	45	6	33	8
3. Doing Mathematical Modeling	25	0	32	0
4. Conducting Student Centered Activities	17	0	50	0
5. Conducting a Teacher Directed Lesson	15	79	18	83
6. Teaching in an Interactive Form	61	32	40	15
7. Leading Students to Construct Concepts	40	12	28	12

promote students' mathematical thinking, and how to establish constructive student-teacher relationships. Both non-PAC volunteers, Debbie and Jay, showed lower percentages of time devoted to reformed teaching practices and their teaching methods did not promote divergent modes of thinking. Lisa and Victor were observed to incorporate greater number of reformed teaching strategies and higher percentages of time doing reformed teaching. In contrast to Debbie's classroom where students were asked to follow the teacher's directions, Lisa's teaching allowed for a more active and engaging learning community.

Lisa, Debbie, and Jay expressed beliefs that mathematics is both useful and fun and enjoyed doing it and teaching it. However, the non-PAC volunteers, Debbie and Jay, taught it more or less as a "cut and dry" subject. Unlike them, Lisa strongly believed that mathematics should be taught in an exciting way by maintaining a dynamic, interactive class. This was clearly evident in her style of teaching. She showed a lot of enthusiasm while she was teaching and her students were the same way. They were eager to participate and learn. Victor did not find mathematics very exciting, but he believed that mathematics is useful and the main focus of mathematics teaching should be on the real life applications of mathematics, not just the theory. The bridge building lesson exemplified his real, applied view of mathematics.

Debbie voiced a preference for traditional teaching in contrast to Lisa, Victor, and Jay who espoused reform-based teaching. Both Lisa and Victor (the PAC volunteers) engaged students in active explorations and investigations of mathematics, and integrated real world applications and the use of technology into their teaching. In contrast, Jay did not display the reform-based teaching actions in his classroom. He and Debbie seemed to have a similar approach to teaching mathematics — teacher lecturing on a topic and the related examples, assigning exercises or simple problems, and asking students to follow the same procedure (that the teacher introduced) for answers. Both of them showed no evidence of incorporating technology in the classroom. While Debbie occasionally involved real world application problems in classroom instruction, Jay did not incorporate them to any extent.

Students in Lisa's classroom used multiple means to represent phenomena (models, symbols, drawings, graphs by computers and graphing calculators, etc.), made conjectures before attempting to solve problems, discussed activities and made decisions on the activities, had opportunities to re-assess their learning, and interacted by sharing and evaluating each other's work. Students in Debbie's classroom, on the other hand, mechanically followed her directions during most of the time, and only sometimes used drawings and manipulatives in algebraic representations. The teacher did all decision making including the evaluation of students' work. Debbie would be considered as a well-prepared and structured teacher, yet this was not reflected in her views of student perspectives and attitudes.

Discussion

Although there were differences among the four student teachers in other aspects, Lisa and Victor were similar in having developed and demonstrated an emergent reformed teaching style during their student teaching while Debbie and Jay were similar in showing more characteristics of a traditional teaching style. The PAC volunteers seemed to come to class with fresh ideas and enlightened concepts, while Debbie and Jay brought an old school mentality. These results are similar to Thompson (1984) who found that “teachers’ beliefs, views, and preferences about mathematics and its teaching, regardless of whether they are consciously or unconsciously held, play a significant, albeit subtle, role in shaping the teachers’ characteristic patterns of instructional behavior” (pp. 124-125). The beliefs, views, and preferences about mathematics and its teaching of Lisa, Victor, and Debbie were exhibited in the ways that they taught their respective classes. The inconsistency between Jay’s conceptualizations and his teaching practice not only showed, as noted by Thompson (1984), “that the teachers’ conceptions are not related in a simple way to their instructional decisions and behavior” (p.124), but implied that Jay might subconsciously hold a preference for traditional teaching.

Similar to Thompson (1992), there is evidence of correspondence between action and belief in the current study. The videotape analyses showed that the student teachers were guided partially by their theories about their students and partially by their views of the meaning of mathematics. Jay and Debbie conducted classes that were teacher directed and professed the view of students as needing guidance to help them do the work because they could not do it alone. In contrast, Lisa and Victor focused more on the use of technology, problem solving and modeling, matching their expressed beliefs in the intelligence of their students. They tended to leave more decisions to students and to be more accepting of their students’ ideas.

The literature suggests that pre-service teachers’ beliefs are heavily drawn from their own experiences as learners (Thompson, 1992). All four of the cases studied attest to the fact that the student teachers relied on those experiences together with their college class experiences. They frequently referred to how they learned mathematics and that this was what guided their planning. The student teachers also expressed feelings of success or failure, or maybe more accurately encouragement or frustration, in ways that corresponded to their style of teaching. For example, Debbie, a task-oriented teacher, expressed that a measure of her success in a lesson was whether all of the students paid attention or not. In contrast, Lisa, a more student-centered teacher, described a successful lesson by the extent of the excitement of the students as they participated.

In summary, from these analyses, one can infer that the optional supplementary experiences, especially the PAC experience, either enhanced or reinforced a positive impact on the development of reform-centered and standards-based pre-service teacher practitioners. The pre-service teachers who had many more supple-

mental experiences performed significantly better in constructing standards-based, reform oriented classrooms than those who had fewer such experiences.

Implications

Based on the findings from this cross-case analysis and other work conducted by the researchers (McClintock, Jiang, & July, 2002), the FIU Mathematics Education faculty have endorsed intensive and extended experiences, particularly those involving modeling, because of their potential for influencing teacher beliefs and values. Such experiences seem to influence student teachers' instructional behaviors, resulting in higher student achievement. Teacher beliefs about mathematics and mathematics instruction are tied to student teachers' confidence in the ability of their students. These beliefs are tied closely to previous experiences and are influenced somewhat, during student teaching, by supervising teachers. These beliefs are reflected in the student teachers' instructional approaches.

To assure that field experiences continue to be meaningful, the faculty will collaborate with PAC teachers to integrate mathematics, science and technology with modeling and project-based approaches. We will continue to seek ways to provide opportunities for more teacher candidates to get involved in the PAC teaching and tutoring activities. In addition, a new course with mathematics content and technology as a tool for modeling will be implemented as a replacement for a currently required course. Workshops for public school supervising teachers will include substantive use of technologies, collaborative learning, and Socratic questioning techniques.

In the interests of accountability for ensuring that reform-based teaching practices are effective, each of these changes will require an assessment of the impact on the pre-service teachers. We intend to base continued program improvement on the results of guided inquiries.

Notes

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