Participants' Focus in a Learner-Centered Technology-Rich Mathematics Professional Development Program

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Leaders in professional development have called for more learner-centered professional development opportunities for teachers. These approaches allow teachers to have some choice about the content and pedagogies on which they focus during professional development courses. This paper shares case studies of three participants from InterMath, a learner-centered professional development program for middle grades mathematics teachers. The findings indicate that participants' backgrounds in both mathematics and technology as well as their goals for the course significantly impacted what they reported learning. The paper concludes with implications for the design and research of learner-centered professional development programs.

Professional development programs and opportunities for teacher learning are an essential component for improving student learning (Joyce & Showers, 2002; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; No Child Left Behind, 2002; National Partnership for Excellence and Accountability in Teaching, 2000a). In the past decade, leaders in professional development have offered recommendations for designing professional development programs (e.g. Guskey, 2003; Hawley & Valli, 1999; Loucks-Horsley et al., 2003; National Partnership for Excellence and Accountability in Teaching [NPEAT], 2000a, 2000b) and theoretical perspectives about how teachers learn (e.g. Cohen & Ball, 1999; Putnam & Borko, 2000; Richardson, 1996). Effective professional development focuses on improving student learning (Hawley & Valli, 1999; Joyce & Showers, 2002), is based on teachers' practice (Cohen & Ball, 1999; Putnam & Borko, 2000), and is designed to give teachers ownership of their learning (Hawley & Valli, 1999; Loucks-Horsley et al., 2003). Furthermore, professional development should allow teachers to collaborate with colleagues (Loucks-Horsley et al., 2003), be carried out over a long period of time (Garet, Porter, Desimone, Briman, & Yoon, 2001; Richardson, 1990), and be closely aligned with goals for comprehensive change and reform (Fullan, 1995). These characteristics embody the description of learner-centered professional development (LCPD) programs developed by the NPEAT (2000b).

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In mathematics education, professional development programs have been cited as an essential part of current reform efforts (National Council of Teachers of Mathematics, 2000). Research indicates that student learning is positively influenced by four teacher characteristics: teachers' content knowledge (Ball, Lubienski, & Mewborn, 2001; Hill, Rowan, & Ball, 2004), pedagogical content knowledge (Marzano, Pickering & Pollock, 2001), teachers' understanding of student thinking (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996) and teachers' use of specific instructional practices such as using technology, hands-on activities, or mathematical manipulatives (National Center for Educational Statistics [NCES], 2001; Wenglinsky, 1998). Intuitively, mathematics professional development programs should focus on these characteristics.

InterMath: Learner-Centered Professional Development

The InterMath project is an example of LCPD designed to impact middle grades mathematics teachers' content knowledge, comfort with technology, and experience with an investigative-based approach to teaching and learning mathematics. Participants have been surprised by the fact that InterMath differs from traditional professional development programs in that it focuses on teachers' content knowledge rather than providing activities that they can take directly into their classrooms. The InterMath research team has also found that teachers tend to get frustrated by the use of technology, especially in the first few class meetings of an InterMath course. From the first meeting, participants actively engage in using technology as a tool to explore mathematical concepts. After a few class meetings, technology remains the primary focus of the class, but many participants realize there is more to InterMath than just learning to use technology. In

our early research, interviews indicated that participants focus to various degrees on the mathematics content, the technology, and the ways they can use the InterMath content in their classrooms.

Courses Discussed in this Paper

This paper presents case studies of three InterMath participants from two InterMath courses: an Algebra course and a Number Sense course. While the courses were taught by different instructors, both featured the same course components. Both courses involved 45 hours of face-to-face classes which involved three major components: discussing investigations that were modeled and led by the instructors, working individually or with a partner on investigations and completing write-ups of solutions, and designing technology-rich investigations to be used in the classroom.

Due to InterMath's learner-centered nature, participants took ownership of the content and investigations. While instructors guided participants through investigations in the respective content areas, participants were able to select investigations from any content area. Despite this freedom, participants in the Number Sense course chose only number sense investigations, and participants in the Algebra course selected only algebra investigations.

Research Design and Methods

In order to more closely examine the teachers' focus during the InterMath course, I conducted post-hoc case studies of three InterMath participants. This study was driven by the following questions:

What do the participants report learning during an InterMath course?

What participant characteristics influence what they report learning?

Participant Selection

The three participants were purposefully selected for this study (Patton, 2002). These participants were chosen because: 1) they all took InterMath during the Fall 2002 semester; 2) the instructors were part of the InterMath research team, ensuring there was high fidelity between the implementation of the course and the syllabus; and 3) the three participants had diverse backgrounds and different reasons for taking the courses. Table 1 describes the demographic information for each participant.

Table 1

Description of Participants

Name	InterMath Course	Position during course	Mathematics background	Teaching Experience
Kendra	Number Sense	5th Grade teacher assistant	No college mathematics courses	1st Year
Lauren	Algebra and Number Sense	Career Exploration teacher	Numerous college mathematics courses	5th Year
Sheila	Algebra	Middle grades mathematics teacher	A few college mathematics courses	8th year

* all names are Pseudonyms

As indicated in the table, Sheila was the only participant that was teaching middle grades mathematics, and she was selected due to the relevance that InterMath had to her job as a classroom teacher. Kendra was selected because she reported having limited mathematics content knowledge and was working with elementary school children while she was taking the course. Lauren was not teaching middle grades mathematics while taking the course but reported having a high level of mathematics content knowledge and comfort with technology. It was my hope that selecting three such different participants would provide insight into how participants' backgrounds, jobs, and goals for the course influenced how they focused on their learning.

Data Sources

Interviews and open-ended survey data were used in this study.

Pre-Course Survey

Participants filled out the pre-course survey during the first class meeting. The instrument included 26 Likert-scale items and four open-ended items about what the participants hoped to learn in the InterMath course. For this study, only the open-ended questions were examined because they were deemed relevant to the research questions. On the pre-course survey, participants were asked to explain their uses of instructional technology in their teaching, why they signed up for InterMath, and what they hoped to learn during the course. On the post-course survey, participants completed the same Likert questions as the pre-survey as well as open-ended questions about what they had learned during the course.

Interviews

Participants were interviewed twice using a semi-structured interview protocol. The research team interviewed participants approximately halfway through the course and during the last course meeting. The interviewers asked participants what they were learning in InterMath and how they felt InterMath had influenced their mathematics content knowledge, views about how to teach mathematics, and views about technology's role in a mathematics classroom.

Analysis

Qualitative analysis methodologies guided by principles of interpretive inquiry (Miles & Huberman, 1994) were used to analyze the interview data and the open-ended survey questions. I examined instances in the interviews during which participants discussed what they hoped to learn, what they had learned, and how they felt this experience would impact their classroom practice. The data were analyzed using each individual as a separate unit of analysis.

I then analyzed each individual interview transcript and open-ended survey response, coding the data. The first set of codes I used originated from my previous experiences with InterMath participants (Table 2). In a spreadsheet, I pasted the coded data along with labels with codes and sub-codes. Preliminary analyses of data from other InterMath participants suggest that InterMath's three-pronged approach of enhancing participants' mathematical content knowledge, proficiency with technology, and learning of mathematics through technology-rich mathematical investigations typically results in the participants' focusing their learning on various parts of the course (Erbas, Umberger, Glazer, & Orrill, 2002; Brown, Erbas, Glazer, Orrill, & Umberger, 2001). Based on those observations and related literature, I constructed preliminary codes about how participants might focus their learning, began to analyze data, and revised the codes according to the initial analysis. The preliminary codes used at the beginning of analysis are in Table 2.

For each participant, I coded and sorted the data and then created sub-codes. I then used the coded data to generate themes for each participant. The themes addressing each participant's experience in InterMath are reported below for the three individual cases.

Table 2

Initial Codes: InterMath Participants Areas of Learning

Category	Description	Citation	Example
Content Knowledge			
Mathematical Content Knowledge (MCK)	The participant discusses learning specific mathematical content or mathematical processes.	Ball, 1994; Ma, 1999	"I learned that the graphs of two linear equations will intersect at only one point unless they are the same line."
Technological Content Knowledge (TCK)	The participant discusses learning specific technology content, such as how to use a piece of software.	Ertmer, 1999; National Research Council, 2002	"I learned how to make graphs from a table in Microsoft Excel."
Pedagogical Content Knowledge			
Mathematical Pedagogical Content Knowledge (MPCK)	The participant discusses learning either how to teach mathematics more effectively or how to better understand students' learning of mathematics.	Schulman, 1987; Marks, 1990	"I learned that I can teach linear equations by giving my students an investigation to solve and letting them discover the mathematics that is embedded."
Knowledge about Teaching with Technology	The participant discusses learning how to integrate technology into a classroom of K-12 students.	Ertmer, 2003; NCES, 1999; NCES, 2002	"I learned how I can use Microsoft Excel with my students to help me teach patterns."

The participants represent a diverse range in terms of their backgrounds: a current middle grades mathematics teacher who wanted to learn how to integrate more technology into her teaching, a teacher who began the course with high comfort with technology and high mathematical knowledge, and a teaching assistant who began the course with low mathematical knowledge and some comfort with technology.

Findings: Three Case Studies

Sheila: A Middle Grades Mathematics Teacher

Background. Sheila was one of the few people teaching mathematics while taking InterMath during that session. On the pre-course survey, Sheila said that she was taking InterMath so she could learn "new concepts and ways to improve my math understanding, so I can better teach my students." In terms of technology, Sheila reported, "I am not afraid to try new things but do not feel as accomplished as many peers in the field of technology." In her mid-point interview, Sheila also reported that she lacked confidence in her knowledge of mathematics because she had not taken a mathematics course in more than a decade. She hoped that InterMath would give her a deeper understanding of mathematics, which would, in turn, make her a more effective teacher.

Learning about technology. Sheila reported that her comfort level with, and views about, technology's role in her mathematics teaching changed during the course. Although Sheila's students did use technology prior to the InterMath course, technology was only used as an add-on or enrichment activity after the mathematics content had been taught. Sheila had experience using spreadsheets, Geometer's SketchPad® (Jackiw, 1990), and other computer-based technologies prior to InterMath, but still she reported a lack of confidence that limited her use of those technologies with her students.

At the end of the course, Sheila reported that she viewed technology as a more powerful tool during those moments of instruction when students discuss specific concepts and struggle to understand information. In her post-course survey, Sheila said:

> I have learned to integrate technology into the unit instead of making it a separate activity. I have more confidence in trying to use the different technologies when the opportunity presents itself as a 'teaching moment.' Now I see technology as being integrated, which is better than how it was before. There are a couple of situations where I had kids that I'll say, 'run back there and open this and

try this.' This year I have a computer that is hooked up all the time to the presenter box.

She talked about the difficulty in getting access to her school's computer lab and that the only way to bring technology into her teaching was to use a computer and a projector. Although this lack of access limits the activities that her students can do with technology, the projector allows Sheila to use technology in ways that enrich the mathematics content she is teaching.

Learning about mathematics. On her pre-course survey and during both interviews, Sheila reported that she wanted to become a more effective mathematics teacher by learning more mathematics. On the pre-course survey she wrote, "[I want to learn] new concepts and ways to improve my math understanding, so I can better teach my students." While she considered herself to be an accomplished middle grades mathematics teacher, Sheila reported she had forgotten a lot of mathematics that she had in college. Furthermore, she felt that she lacked a thorough understanding of some of the mathematical concepts that she taught. Her feeling that she lacked mathematical knowledge and her belief that contemporary teaching practices had changed since she was a student motivated her to learn more mathematics and new ways to teach mathematics.

Completing investigations in InterMath. In her post-course interview, Sheila said that to successfully use new teaching strategies (e.g. mathematical investigations), she would have to not only experience learning in this new way but also be more comfortable with the content in order to help her students when they had struggles and questions about mathematics. She reported in an interview, "I was taught [mathematics] in a different way. I was one of those who were taught math by memorizing, and I wanted to [teach] in a more contemporary style that would benefit the students."

At the end of the course, Sheila reported that she was "comfortable enough to get in there and try investigations." Completing the write-ups gave Sheila a better appreciation of her students' struggles with problem solving. She said in her post-course interview:

> I have a better appreciation of my students' struggles. I can better empathize with, oh, they've heard this concept or they've heard or seen this, that, or the other … but when I put it in writing … I can see where it has been hard to grasp. And at the same time, I now know better how to say well, go for it. Work this out. Where do you think this is going to go? Well, try this.

By working on the investigations, Sheila not only has a deeper understanding of mathematics, but also has a better idea of how to guide her students through the problem solving process.

Lauren: High Mathematics Content Knowledge, High Comfort with Technology

Background. Lauren was taking both the Algebra and the Number Sense courses because she was working with a provisional teacher certification. She needed to earn ten professional learning units (PLUs), which she could do by completing two InterMath courses. Lauren reported that she already had a strong mathematics background and a high comfort level using technology. Lauren's secondary motive for taking the InterMath courses was to learn how to use technology more effectively in her teaching. At the time of the course, she was teaching Spanish and Career Explorations, a course in which students apply mathematical concepts in real-world activities, such as setting up budgets, calculating interest on credit cards, and planning their own businesses.

Integrating technology into her teaching. Prior to InterMath, Lauren had extensive experience creating web pages and using spreadsheets for budgets. She felt that her next step was to carry her technology skills into her classroom, which she did a few times while taking InterMath. In her mid-point interview, Lauren explained:

> One day we talked about credit card risk. We tried to figure out how long it would take to pay back credit card debt if you only paid the minimum payment. Luckily, I had a computer right there so I threw it on an Excel spreadsheet. They thought it was great, and they were doing the same thing in their business education class. They were just learning how to do that, so they were excited to see it elsewhere, too…

Lauren extended this activity during the next class period by having her students apply the concept of interest rates using both calculators and spreadsheets. Her students used both technologies and then discussed which technology was more useful in solving the problem that she posed. She reported:

> [The credit card activity] was initially set up using calculators. So what I did was — there were two separate charts. I had them first use the calculator, then showed them how much easier it was using a spreadsheet. They then did the second chart completely on the spreadsheet.

In this activity, Lauren was able to integrate not only technology but also multiple forms of technology, which is emphasized in InterMath. The InterMath investigations allow participants to use multiple technologies to explore the mathematics, and Lauren was able to extend this idea into her classroom as her students used both spreadsheets and calculators to explore the idea of credit card interest.

Lauren reported that she uses technology "as often as I can in my teaching." She feels that using technology in schools is essential since the students have access to it at home and they will be required to use computers when they enter the workforce. From an instructional perspective, Lauren sees technology as a "tool in a teacher's repertoire" that provides more avenues for learning.

Beliefs about mathematics. While Lauren learned a great deal about integrating technology into her classroom, she reported that her biggest takeaway from InterMath was a shift in her views about mathematics. The investigations that she completed allowed her to explore and continually unpack mathematics and see connections between various mathematical concepts.

> I was doing an investigation the other day, and it was just a pattern, and it turned out to be this investigation that had to do with relatively prime numbers. And I would have never thought of that as — it could have been just a fun little thing — find the pattern, but as I went through it more, I was, like, wait a minute, this happens here and it was a mathematical relationship that just came about because of this pattern in this problem…one investigation can contain a number of different math concepts across various content areas that can continue to unfold as the learner digs deeper and deeper into each problem.

InterMath convinced Lauren that mathematics classes should get away from the traditional approach in which facts are accepted as stated and enable her students to explore and figure out why certain mathematical concepts are true. Lauren stated that mathematics teachers should "teach students a way to think, rather than simply a way to do or solve problems."

Lauren repeatedly mentioned in interviews that technology can help students learn mathematics, but it must be used appropriately:

> Kids think it's neat. They think the computer is solving problems for them. They think that a computer will just answer. They don't realize that they need to know the math in order to put the correct formula in the computer … they don't know that they are doing math and things like algebra, but they are.

Kendra: Low Mathematics Content Knowledge, Some Comfort with Technology

Background. During the InterMath course, Kendra was a paraprofessional in a 5th grade classroom, and she hoped to gain her teaching certificate and teach elementary school the following year. Kendra came into the course with very limited mathematics content knowledge. She had not taken a mathematics course since she graduated from high school more than a decade before her participation in InterMath. In terms of technology, Kendra described herself as, "Not very comfortable but very open to learning." Kendra had seen students use computer-based drills and practice software in mathematics, but had no experience using any of the InterMath technologies. On the pre-course survey, Kendra said that she hoped to learn "how we can use the computers more effectively to supplement teaching."

Learning mathematics. On the pre-course survey, Kendra saw InterMath as a technology course, and did not report any intentions of learning mathematics. Throughout the course, Kendra recognized that InterMath was also a mathematics course, as she experienced learning mathematics in a way that was different. Kendra reported:

> It has been a different classroom environment from what I have seen in the past. I have never been in a math class that we discussed so much, immensely … really improved my level of confidence with my mathematical ability. I'm surprised how much I have been capable of now, especially in problem solving.

This new experience shifted Kendra's perspective about how mathematics should be taught towards a more hands-on approach that gives students the chance to discuss the problems they are solving. Kendra's experience in previous mathematics was, "this is how you do it, do these problems, and we will see you tomorrow." Kendra reported being amazed at how much mathematics she learned by completing the investigations.

Learning technology. Kendra had no experience with any of the InterMath technologies prior to the course but left with what she reported as "substantial knowledge" in regards to solving problems by using formulas, functions, and the graphing tools in Excel. When asked if she could use Excel to help her go through an investigation, she said, "I am pretty confident. I'd like to practice even more but I certainly feel more confident now in working with them on my own."

Despite being in an elementary classroom that has three computers, Kendra had not seen computers used in mathematics lessons other than situations in which students played skills-based games. While she thinks that the potential is there for technology to enhance student learning, Kendra offered numerous ideas about why technology may not be appropriate in elementary schools. She cited problems with technology access, finding time to use technology, and having to manage a classroom when the students were using the technology. While Kendra is convinced that technology can help teachers, like herself, learn mathematics, she is still skeptical that technology is appropriate for helping elementary students learn mathematics.

Discussion

In each of the three case studies, participants reported leaving InterMath with more knowledge about mathematics, approaches to teaching mathematics, ways to use technology, and strategies for integrating technology into mathematics classrooms.

Learning Mathematics

All three participants' learning related to mathematics centered on the process of completing InterMath investigations. During the interviews, Sheila and Kendra both shared that their K-12 experiences of learning mathematics were drastically different from those they had in InterMath. Further, Sheila believed that, in order to be effective, she needed to experience learning in the manner in which she was expected to teach. Lauren had a strong mathematics background prior to InterMath but reported learning about connecting mathematical ideas while exploring an investigation. Specifically, Lauren contended that mathematics instruction needs to focus on "a way to think rather than a way to do."

Despite the participants' diverse mathematical backgrounds, each reported an increased comfort in learning mathematics through an investigation-based approach. Each participant reported seeing the value of completing mathematical investigations. Sheila and Kendra explicitly recognized the importance of being comfortable solving investigations prior to using them with their students. This finding supports Cohen and Ball's (1990) sentiment that teachers must experience learning mathematics in the same manner as they are expected to use it in their teaching.

Learning Related to Technology

Prior to the course, Lauren and Sheila reported being comfortable with technology, while Kendra had

never used any of the InterMath technologies. Lauren's strong background with technology enabled her to focus on integrating technology and InterMath-like investigations into her classroom. As seen in her credit card lesson, Lauren reported being able to use multiple technologies to allow students to gain a deeper understanding of interest rates. Sheila reported a shift in her views about technology, such that technology was now a tool that could be woven into her mathematics classroom rather than being used as an add-on. This affordance of being able to focus on how technology could be used in her classroom was not available to Kendra, since her lack of experience required her to focus her learning on mastering the basics of each technology. This finding supports a variety of technology integration models that contend that teachers must first develop basic technology skills before considering how to integrate them in their classroom (Dwyer, Ringstaff, & Sandholtz, 1991; Hooper & Rieber, 1995; Mandinach & Cline, 1992). In Kendra's case, more extensive time with the technology would allow her to master the basic skills so she could more closely attend to how these technologies might be used with her future students.

Implications for Research

This paper presents the cases of three participants with different backgrounds and different reasons for enrolling in an InterMath course. The findings indicate there are individualized benefits for participants who are learning in a learner-centered professional development program that is aimed at developing participants' mathematical content knowledge, technology skills, and comfort with mathematical investigations. Professional development programs that allow teachers to take ownership of their learning and give teachers choices about the content and the activities in which they engage have been highly regarded (Hawley & Valli, 1999; Loucks-Horsley et al., 2003; NPEAT, 2000a). However, these programs can be problematic. In this paper, InterMath participants focused, to varying degrees, on the mathematics, the technology, and the process of doing investigations. Further research is needed to more closely examine the ways in which participants decide how to focus their learning.

While these case studies begin to examine participants' focus in a learner-centered professional development program with multiple foci, further studies in this area are needed to generalize the findings presented here. Future studies should examine more participants that have similar backgrounds (e.g.,

middle grades mathematics teachers, participants that report having high comfort with technology and mathematics, etc.). Finally, the current emphasis in professional development is on making a link between teacher learning to both their classroom practices and their students' learning (Guskey, 2000; NCLB, 2002), and in order to address these issues, longitudinal studies are needed to examine participants prior to InterMath, during the course(s), and then examine teachers' instructional practices and their students' mathematical learning in their classrooms.

This study indicates that InterMath, a learner-centered professional development program, enhanced participants' mathematical content knowledge, technological skills, and comfort with mathematical investigations. Future studies will provide further evidence about how, and the extent to which, teachers learn during these experiences.

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