EXAMINING THE INFLUENCE OF LEARNER-CENTERED PROFESSIONAL DEVELOPMENT ON ELEMENTARY MATHEMATICS TEACHERS' INSTRUCTONAL PRACTICES, ESPOUSED PRACTICES AND EVIDENCE OF STUDENT LEARNING

by

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(Under the Direction of Michael J. Hannafin)

ABSTRACT

This study examined the extent to which two elementary teachers' classroom practices were aligned with their intentions, self-reported implementation, and the practices emphasized during ongoing learner-centered professional development (LCPD) program designed to the support the integration of learner-centered mathematical tasks and associated pedagogies. Evidence of student activity associated with enactments was also examined.

Data were collected related to intended (i.e., what they planned to do), enacted (i.e., what they were observed doing), and espoused practices (i.e., what they believed they did). Teachers were observed when they indicated their intent to implement practices consistent with the professional development instructional practices and were interviewed to identify their intended and espoused practices.

Task enactments were taken directly from professional development activities (direct adoption), co-planned with project personnel, or independently planned by the teacher-participants. The Video Analysis Tool (VAT) was used to code instances of the six professional development instructional practices (i.e., tasks, questions, algorithms, technology, student communication, and mathematical representations) using a scale that codified the extent to which they implemented the pedagogies. Interview data were analyzed using the same instructional practices as primary codes.

Findings indicated that the majority of enactments did not align with the professional development instructional practices. Enactments and instructional practices were more consistent with the professional development pedagogies when professional developers scaffolded the tasks, but even highly scaffolded tasks were often implemented didactically. Evidence also suggested that instruction became increasingly learner-centered as the professional development progressed. Latter enactments included more learner-centered attributes than at the beginning of the study, though relatively few were observed. Learner-centered enactments included more student-generated mathematical representations, communication about mathematical thinking and sharing of mathematical work through various representations (e.g., using manipulatives, tables, computations).

Further research is needed to examine the influence of on-site support during teachers' enactments, changes in teacher practice, and the alignment among intentions, self-reports, and actual practices. Design experiments might better refine and modify professional development programs using ongoing, real-time evidence of teacher and student performance. Finally, research is needed to further explore and establish links among teacher learning, classroom implementations, and student learning.

INDEX WORDS: Professional development, learner-centered, mathematical tasks, elementary school education

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DEDICATION

I dedicate this work to the following people:

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- My friends who provided support during the past four years;
- My “Montague Moms” and Mr. Walk who helped launch my career as a teacher;
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STATEMENT OF THE PROBLEM

Student Achievement in Mathematics

Analyses of large-scale mathematics assessments indicate that American students are underachieving in mathematics. These measures indicate that students are failing to reach benchmarks set by the American government as well as the achievement levels of students in other developed nations (National Center for Educational Statistics [NCES], 2000; 2004). The story is similar in Georgia, where student performance on the 4^{th} grade mathematics section of the 2003 National Assessment for Educational Progress (NAEP) was five points below the national average (230 compared to 235). Further, 73% of the state's 4th graders scored below "proficient" compared to 68% nationwide (NCES, 2004).

Analyses of student scores on large-scale tests and teachers' self-reports of practice have identified specific instructional practices that influence student achievement. A correlation study showed a positive relationship between teachers' self-report that they emphasized higher-order thinking and hands-on activities during instruction and student performance on the 1999 NAEP mathematics test. Students whose teachers reported using those practices scored one-half a grade level higher than their peers (Milken Family Foundation, 2000). Another researcher reported a positive correlation between reported technology use by 4^{th} graders to develop higher-order skills and scores on the 1996 NAEP mathematics test (Wenglinsky, 1998).

Scholars (Bransford, Sherwood, Hasselbring, Kinzer, & Williams 1990; Bransford, Brown, and Cocking, 2000; Cognition and Technology Group at Vanderbilt [CTGV], 1992, 1997; Hannafin, 1992; Jonassen & Reeves, 1996) and national educational organizations (CEO Forum, 2001; National Council for Teachers of Mathematics [NCTM], 2000; National Research Council, 1996; National Council of Teachers of English, 1996) advocate integrating technology in ways that develop both conceptual understanding and higher-order thinking skills—a shift toward learner-centered instruction. McCombs and Whisler (1997) described learner-centered environments as places where learners engage in complex and relevant activities, collaborate with their peers, and employ resources such as technology to collect, analyze and represent information. While these approaches have potential to impact student learning, evidence of their use in schools is limited (McCombs, 2001, 2003). Researchers examining the implementation of learner-centered activities have reported that teachers tend to implement pre-designed activities didactically by supplying rote algorithms for students to follow (CTGV, 1992; Doyle, 1988; Greeno, 1983). A recent synthesis of research indicated that numerous teacher factors, such as content knowledge, pedagogical content knowledge, beliefs and their interpretation of the curriculum influenced how learner-centered activities are enacted in classrooms (Remillard, 2005). To this end, teachers need support in order to implement leaner-centered activities effectively in their classroom (NPEAT, 2000a).

Mathematics and Learner-centered Tasks

The field of mathematics education has advocated learner-centered activities and investigative approaches to mathematics for nearly two decades (NCTM, 1989, 2000;

Schoenfeld, 1992). These learner-centered mathematical activities have been referred to as mathematical tasks (Henningsen & Stein, 1997; NCTM, 2000; Stein, Grover, & Henningsen, 1996). Mathematical tasks are critical to students' learning because "tasks convey messages about what mathematics is and what doing mathematics entails" (NCTM, 1991, p. 24).

Further, the use of technologies, such as calculators and spreadsheets has been recommended by the mathematics education field (NCTM, 2000). According to NCTM, using technology to complete learner-centered tasks provides students with mathematical power, which they define as, "An individual's abilities to explore, conjecture, and reason logically, as well as the ability to use a variety of mathematical methods effectively to solve non-routine problems" (NCTM, 1989, p. 5).

Professional Development's Role in Improving Student Learning

If teachers are expected to impact student learning through technology-rich tasks, teachers need opportunities to learn with and about technology, as well as how to integrate technology-enhanced activities into their classroom teaching (Culp, Honey and Mandinach, 2003; Sandholtz, Ringstaff, & Dwyer, 1997; Schrum, 1999). In the past decade, leaders in professional development have presented theoretical perspectives about how teachers learn (Cohen & Ball, 1999; Putnam & Borko, 2000; Richardson, 1996) and recommended principles for effective professional development programs (e.g., Guskey, 2003). These recommendations include:

- focusing on issues related to student learning (Hawley & Valli, 1999);
- allowing teachers to take ownership of their learning (Hawley & Valli, 1999; Loucks-Horsley, Love, Stiles, Mundry, & Hewson 2003);

- addressing specific content and pedagogies (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996; Desimone, Porter, Garet, Yoon, & Birman, 2002);
- providing opportunities for teachers to reflect and learn from their own practice (National Partnership for Educational Accountability in Teaching [NPEAT], 2000a, 2000b; Putnam & Borko, 2000; Schon, 1983);
- allowing teachers to collaborate with each other and with project staff (Sparks & Hirsch, 2000); and
- providing ongoing and comprehensive activities (Loucks-Horsley et al., 2003; Richardson, 1996).

In essence, these documents call for professional development to support learner-centered approaches to teacher learning (Hawley & Valli, 1999, NPEAT, 2000a, 2000b).

In mathematics, promising approaches to learner-centered professional development instruction have been advanced. These learner-centered programs allowed teachers to focus on student learning by having them watch videos of their own classroom instruction (Sherin & van Es, 2005), examine student work samples (Carpenter, Fennema, & Franke, 1996; Fennema et al., 1996), and make instructional decisions based on their analysis of student work (Fennema et al., 1996; Schifter & Simon, 1992; Simon & Schifter, 1991). The QUASAR (Quantitative Understandings: Amplifying Student Achievement and Reasoning) project established school-based communities, where teachers collaborated with each other and university faculty to develop and implement reform-based curricula in their classroom (Silver, Smith, & Nelson, 1995; Silver & Stein, 1996). Each of these approaches provided teachers with the opportunity to take ownership of their learning as they designed and modified instruction for their students. Further, every project lasted over a year, providing teachers with sustained and on-going support. While these projects have provided insight into the influence of learner-centered professional development on both teachers' and students' learning, more research is needed to examine how teachers enact mathematical tasks into their classroom.

Multi-level Impact of Professional Development

According to Guskey (2000), professional development has the potential to impact learners on five levels: participants' reactions, participants' learning, organization support and change, participants' use of new knowledge and skills, and student learning outcomes. Typically, professional development research has focused mainly on participants' reactions (Level One) and learning (Level Two) (Borko, 2004; Guskey, 2000), such as by completing questionnaire regarding their reactions and perceptions about what has been learned. Recently, researchers have begun to expand the focus to address the impact of professional development on organization and school change (Level Three), participants' classroom practices (Level Four) and student learning outcomes (Level Five) (Carpenter, Fennema, & Franke, 1996; Fishman, Marx, Best, & Tal, 2003; Knezek & Christensen, 2004; Kubitskey, Fishman, & Marx, 2003). This shift is consistent with state and national policies, which have reinforced the importance of linking teacher professional development to student learning. The No Child Left Behind Act (NCLB, 2002) mandates that all federal funds dispersed for professional development require an examination of the program's influence on student achievement. Further, Georgia legislation has mandated that all professional development funds be allocated towards activities that are likely to impact student achievement. Georgia's *A*

Plus Education Reform Act of 2000: House Bill 1187 (Georgia House of Representatives, 2000) states that “where possible, staff and professional funds shall be used for activities that enhance the skills of certificated personnel and directly relate to student achievement.”

Problem

The influence of professional development programs designed to support technology-rich mathematical tasks on teachers’ instructional practices and their students’ learning outcomes have not been studied comprehensively. Research methods often focus largely or solely on teacher’s attitudes about professional development and perceptions of technology skills; rarely have researchers addressed how teachers apply their knowledge and skill in their instruction, or whether such practices influence student learning. Level four and five examination requires clearly defined goals as well as methods and instruments that link validated teaching practices emphasized during professional development, evidence of classroom implementation of such practices, and corresponding indicators of student performance (Guskey, 2000).

The limited amount of available professional development research related to learner-centered, technology-rich tasks suggests that the focus includes content, technology skill, classroom implementation, and combinations of each (Polly, Orrill, Ledford, & Bleich, 2005; Orrill, Calhoun, & Sikes, 2002). Stein, Grover, and Henningsen (1996) contend that teachers’ understanding and use of mathematical tasks are influenced by their mathematical content knowledge, knowledge of students, and instructional habits. When tasks are technology-rich, teachers also need to create and maintain environments where technology can support mathematical learning.

While learner-centered approaches to professional development have been recommended (Hawley & Valli, 1999; NPEAT, 2000a, 2000b), empirical research is needed to examine how learner-centered professional development programs influence teachers' classroom practices and their students' learning. If provided with learner-centered opportunities to develop the knowledge and skills needed to effectively integrate technology-rich activities into their classroom, teachers may better influence their students' learning.

Purpose of the Study

This study examined changes in mathematics beliefs and practices among elementary school teachers participating in a learner-centered, professional development program. The professional development program was designed to prepare participants to teach mathematics in an investigative manner, integrate technology-rich mathematical tasks into their classroom instruction, and attend closely to students' mathematical thinking.

Three research questions guided this study:

1. *To what extent (and how) do teachers enact the practices emphasized in a learner-centered professional development during their mathematics teaching?*
2. *How do teachers' enactments of the practices emphasized during learner-centered professional development compare with their espoused and intended practices?*
3. *How does evidence of student understanding reflect their teachers' enacted practices?*

Chapter II

THEORETICAL FRAMEWORK

The focus on providing rich opportunities for teacher learning has increased in recent decades (Borko, 2005). While national organizations (e.g., National Staff Development Council [NSDC], 2001; National Partnership for Education and Accountability in Teaching [NPEAT], 2000a, 2000b) and leaders in professional development (e.g., Hawley & Valli, 1999; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Putnam & Borko, 2000; Sparks & Hirsch, 2000) have published recommendations for improving teacher learning, research studies documenting the impact of ongoing efforts are scarce. Research has primarily emphasized teacher perceptions of their professional learning opportunities rather than application to classroom instruction (Guskey, 2005).

In addition, despite spending billions of dollars on educational reforms in the past two decades, little evidence indicates that the financial investment made by states and the national government have increased student learning in America’s schools (National Center for Educational Statistics [NCES], 2000; 2004). Increasingly, contradictions have arisen about what constitutes student learning. Federal policies, such as the No Child Left Behind Act (NCLB, 2002) view scores on standards-based tests as the primary valid indicator of student learning. Meanwhile, standards published by national educational organizations (e.g., National Council of Teachers of Mathematics [NCTM], 1989, 2000; the National Research Council [NRC], 1996; National Council of Teachers of English

[NCTE], 1996) view both standards-based tests and performance-based tasks as valid evidence of student learning. Performance-based tasks could be used under NCLB, but the mandate to test every child limits its feasibility due to the time and cost involved in creating and scoring performance-based measures.

Further, academic standards increasingly call for teachers to establish learner-centered classrooms (McCombs & Whisler, 1997) that require learners to synthesize, analyze and evaluate information (NCTE, 1996), form and test conjectures (NCTM, 2000) and engage in inquiry-based activities (NRC, 1996). In mathematics, the NCTM (2000) *Principles and Standards* call for the implementation of instructional practices consistent with learner-centered tasks, assuming that student performance on both standards-based and performance-based assessments will improve. This argument is supported by research indicating a positive correlation between teachers' self-reported use of hands-on higher-order mathematical thinking tasks and students' mathematics scores on the 4^{th} grade 1999 National Assessment for Educational Progress (NAEP). However, despite correlation evidence of positive impact on student learning, fewer than 25% of teachers reported they used hands-on activities in their mathematics classrooms (Milken Family Foundation, 2000).

Learner-centered activities have the potential to increase student learning on measures of both standards-based and performance-based assessments. However, previous research indicates the need to identify effective ways to support teachers' use of these tasks. In the following, I argue for professional development programs that support the enactment of learner-centered activities in K-12 schools, and propose a research agenda that examines teacher learning as well as its impact on classroom practices and student learning.

Learner-Centered Tasks, Technology, and Student Learning: A Primer

Learner-centered classrooms gained prominence with the publication of the *American Psychological Association's Learner-Centered Principles* (APA, 1997). The American Psychological Association published the *Learner-Centered Principles for Instruction* (APA Work Group of the Board of Educational Affairs, 1997) in response to a need for research-based recommendations for educational reforms (Alexander & Murphy, 1998). This research base draws from the fields of educational psychology and psychology, and provides principles that should be considered when designing learning environments for K-adult learners (Alexander & Murphy, 1998). Subsequently, these principles have been adapted for K-12 learning and championed as a framework for educational reform (McCombs & Whisler, 1997; McCombs, 2001, 2003).

According to Doyle (1983), academic tasks focus on three facets of student's work: (a) products that students formulate, (b) process of generating the product and (c) resources available to students as they generate the product. Doyle concluded that learning tasks "are defined by the answers students are required to produce and the routes that can be used to obtain these answers" (p. 161). Consistent with Doyle's (1983) characterization, for purposes of this study, learner-centered tasks comprise instructional activities that are aligned with the *Learner-Centered Principles*. Based on McCombs and Whisler's (1997) work and the *Learner-centered Principles* (APA, 1997), Table 2.1 synthesizes the characteristics of learner-centered tasks.

Table 2.1: Characteristics of Learner-Centered Tasks (Adapted from McCombs & Whisler, 1997).

Task	Characteristic	Learner-centered tasks	Learner-Centered Principles (APA Work Group, 1997)
Design	Relevant	Personally relevant to students' lives and build upon prior experience or prior knowledge.	The learning of complex subject matter is most effective when learners construct meaning from information and experience (Principle 1). The successful learner can link new information with existing knowledge in meaningful ways (Principle 3). An individual's motivation is influenced by their beliefs and interests (Principle 7), the learner's creativity and curiosity (Principle 8), and their background and experiences (Principles 10, 12 and 13).
	Student-directed	Designed so that learners have ownership of the tasks they are completing, have, are able to choose their approach and have some influence about how the products of the task are represented.	An individual's motivation is influenced by their beliefs and interests (Principle 7), the learner's creativity and curiosity (Principle 8), and their background and experiences (Principles 10, 12 and 13).
	Reflective	Reflective and allow learners to refine their understanding and make connections between concepts or approaches used to complete the task.	Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking (Principle 5).
	Assessment	Aligned with assessment so that learning is evaluated in the context of the task.	Setting appropriately high and challenging standards and assessing the learner as well as learning progress -- including diagnostic, process, and outcome assessment -- are integral parts of the learning process (Principle 14).
	Technology-rich	Able to be supported with technology that allows students to gather information, explore concepts, collaborate with peers or represent knowledge.	Learning is influenced by environmental factors, including culture, technology, and instructional practices (Principle 6).
Implementation	Facilitated	Facilitated by teachers or peers that model, scaffold student learning and facilitate the completion of the tasks.	The successful learner, over time and with support, can create meaningful, coherent representations of knowledge (Principle 2).
	Collaborative	Implemented in a manner that allows students to collaborate and share ideas with one another.	Social interactions, interpersonal relations, and communication with others all provide opportunities for learning (Principle 11).

Learner-centered tasks are relevant to learners, allowing them to create meaning from their experiences. In learner-centered tasks, students assume ownership of their learning by identifying questions, investigating phenomena, synthesizing information and representing their newly formed knowledge in products. Tasks can vary in complexity and difficulty and place different cognitive demands on students (Hiebert & Wearne, 1993). Thus, the teacher supports learner-centered tasks by modeling processes, scaffolding student knowledge construction, guiding thinking, and facilitating reflection as students evaluate what they learn.

Technology and Learner-Centered Tasks

Technology has been recommended as a resource to support learner-centered instruction (e.g., APA, 1997; Bransford, Brown, & Cocking, 2000; International Society for Technology in Education, 2000). Educational theorists have characterized technology as a tool to support learner-centered tasks (see Bransford et al., 2000, Cognition and Technology Group at Vanderbilt [CTGV], 1997; Hannafin, 1992; Jonassen & Reeves, 1996; McCombs, 2003; NRC, 2000; Papert, 1980). Apple Classrooms of Tomorrow (ACOT) researchers reported that teachers, as part of an extensive, multi-year professional development project, began integrating technology in their classrooms and their instruction shifted from a didactic to learner-centered (Sandholtz, Ringstaff, & Dwyer, 1997). ACOT students used technology to create products (e.g., instructional materials for other students), explore complex problems (e.g., determining how to conserve the world’s energy sources), and examine real-world scenarios (e.g., planning a budget for a vacation).

While the potential to facilitate student learning is apparent, research on technology's impact on learning has yielded mixed results. Despite voluminous published research (e.g., Mann, 1999; Sandholtz, Ringstaff, & Dwyer, 1997; Ringstaff & Kelley, 2002; Roschelle, Pea, Hoadley, Gordin, & Means, 2001; Schacter, 1999; Wenglinsky, 1998), it has proven problematic for researchers to establish relationships between technology and student learning without accounting for the manner in which technology is used (Roschelle et al., 2001). Research indicates that technology impacts learning positively when associated with learner-centered activities, such as when students use technology to facilitate problem solving, conceptual development, and critical thinking (Cognition and Technology Group at Vanderbilt: CTGV, 1992; Means, 1994; Sandholtz, Ringstaff, & Dwyer, 1997; Ringstaff & Kelley, 2002; Wenglinsky, 1998).

Wenglinsky (1998) analyzed student's performance on the 1996 8th grade National Assessment of Educational Progress (NAEP) mathematics test and found that students whose teachers reported using technology in conjunction with learner-centered pedagogies scored significantly higher than their peers whose teachers did not. Conversely, research also suggests possible detrimental technology effects when implemented didactically, such as focusing only on procedural knowledge rather than students' conceptual understanding. An analysis of the 2000 NAEP mathematics data indicated that 8th graders who used technology for mathematics drill and practice scored significantly lower than their peers who used no technology (NCES, 2000). Clearly, technology's impact on student learning varies according to the nature of the learning task and the manner in which it is used.

Dilemmas with the enactment of learner-centered tasks

Discrepancies between teachers' intended use and enactment of learner-centered tasks, common in the carryover of professional development programs to everyday teaching-learning practices, are both pervasive and significant. In science education, for example, the University of Michigan's Center for Learning Technologies in Urban Schools (LeTUS) project provided urban school districts in Detroit and Chicago with reform-based science curriculum and professional development to support the enactment of these materials. While multiple LeTUS studies have reported a high level of implementation based on teacher surveys and classroom observations (Fishman et al., 2003; Kubitskey et al., 2003), some teachers reverted to traditional approaches when confronted with time constraints, unfamiliar content, and problems with technology (Schneider, Krajcik, & Blumenfeld, 2005). LeTUS researchers reported that teachers complained about the extended time needed to complete their typical didactic science lessons. According to Doyle (1988), higher-level tasks, consistent with the learner-centered principles, are often more complex in nature and take longer to implement than traditional classroom activities. In such circumstances, teachers tended to supply answers or specify procedures to speed up students' task completion.

Teachers in the *Jasper Woodbury* project posed pre-designed tasks that required students to view an *adventure* on a video-disc, identify needed information, determine how to examine a task, and apply their solutions to an immediate sub-problem (CTGV, 1997). Classroom observations suggested that many teachers were reluctant to depend on the pre-packaged materials or allow their students to take responsibility for their learning (CTGV, 1992). Others modified Jasper tasks by providing drill-and-practice worksheets that addressed the same skills embedded in the video scenarios (CTGV, 1992). Some teachers even provided algorithms to solve Jasper's open-ended problems which were designed to promote student analysis, investigation, and problem solving skills.

Analyses of enacted learner-centered curricula. While numerous curriculum reforms have been designed to support learner-centered instruction, research indicates that teachers experience numerous problems enacting such curricula in their classrooms. Kim and Stein's (2006) analysis of two learner-centered mathematics curricula,implementations, *Investigations in Number, Data and Space* (TERC, 2004) and *Everyday Mathematics* (University of Chicago School Mathematics Project, 2004), showed that teachers' enactment became increasingly didactic in both cases. With the more learner-centered curriculum, *Investigations*, teachers posed numerous learner-centered tasks but provided explicit algorithms which students used to complete the task. In the case of *Everyday Mathematics*, a majority of the implementations included the same type of task (e.g. division by a 1-digit divisor); students used the same traditional algorithms repeatedly to complete the tasks.

Remillard (2005) analyzed 25 years of research on teachers' enactment of reform-based mathematics curricula across grade levels and found wide variations between the curricula author's intended use (referred to as *intended curriculum*) and its actual enactment in classrooms (referred to as *enacted curriculum*). Many factors influenced teachers' enactment of intended curricula, including pedagogical content knowledge, subject matter knowledge, beliefs, goals and experiences, capacity to design instruction, perception of curriculum, perception of their students, tolerance for student discomfort, and identity as a teacher. Clearly, while the design of learner-centered curricula can support the implementation of learner-centered instruction, they are not sufficient to ensure effective classroom implementation. Teachers need on-going support to develop the knowledge and skills necessary to successfully enact learner-centered tasks and positively influence student learning (Hawley & Valli, 1999; Loucks-Horsley et al., 2003). Research is needed to determine how to best support teachers' enactment of learner-centered curriculum in everyday classrooms.

Enactment of mathematical tasks. Doyle (1983, 1988; Doyle et al., 1985) observed teachers attempting to implement complex mathematical tasks found that teachers frequently simplified tasks to alleviate students' struggles and speed up task completion. Teachers modeled specific algorithms for their students and provided the procedures needed to solve the tasks. While students worked independently on mathematical tasks, the teacher explicitly linked the algorithms to the students' tasks and told them which procedures to use (Doyle et al., 1985). Doyle (1983) noted that assessments emphasized the content and procedures that were modeled and explained rather than the problem-solving skills the tasks were designed to promote.

Doyle et al. (1985) also noted that the number of tasks completed was largely unrelated to the amount of learning that occurred. Although the students completed numerous mathematical tasks, coverage was not expanded thus serving as a review rather than an extension of skills and concepts already learned. In effect, the tasks emphasized application of previously-learned algorithms or routinized procedures rather than novel work, in which students make decisions about how to approach and complete the tasks. In mathematics, multi-step problems require the student to choose which operations to use and which numbers to include in their work (Doyle, 1988).

The QUASAR project provided teachers with professional development opportunities to learn with, design, and implement worthwhile mathematical tasks in their classrooms (Henningsen & Stein, 1997). Researchers observed that teachers' enactment of mathematical tasks was influenced by their desire to avoid student frustration. In an effort to minimize frustration, they regressed to didactic, teacher-centered instruction:

> In many instances, teachers appeared to find it difficult to stand by and watch students struggle, and they would step in prematurely to relieve them of their uncertainty and (sometimes) emotional distress at not being able to make headway. All too often, however, teachers would do too much for their students, taking away students' opportunities to discover and make progress on their own. (Stein, Grover & Henningsen, 1996, p. 480)

Evidence from a wide range of studies underscores the variety of dilemmas teachers confront while enacting learner-centered tasks in their classrooms. Since teacher enactment influences both what and how students come to learn and understand mathematics, it is crucial to clarify the attributes of learner-centered instruction in both principle and practice, to prepare teachers in those principles and practices, and to document the connections between everyday classroom enactment and student learning. In the following section, we examine link between learner-centered principles and learner-centered professional development.

A Framework for Learner-Centered Professional Development

Table 2.2 lists six primary characteristics of learner-centered professional development (LCPD). These characteristics were identified by synthesizing recommendations for professional development (Guskey, 2003; Hawley & Valli, 1999; Loucks-Horsley et al., 2003; NPEAT, 2000a), APA's learner-centered principles (APA Work Group, 1997) and research studies on professional development projects. Table 2.3 identifies professional development programs that embody learner-centered characteristics, and Table 2.4 details the methods used and research findings reported from each program. [1]

Student-focused

According to the *Learner-Centered Principles* (APA Work Group, 1997) learners construct knowledge by associating information with their experiences (Principle 1). Further, Principle 2 posits that learning can be enhanced when students are guided and supported over time by others. The teacher can provide opportunities for learners to design, implement, and guide these learning experiences (McCombs & Whisler, 1997). A primary goal of professional development, therefore, should be to improve student learning (NPEAT, 2000a; Hawley & Valli, 1999). Professional development programs need to prepare teachers to design learner-centered tasks, examine students' work, identify problems students encounter, and guide students through the learning process (Hawley & Valli, 2000; Loucks-Horsley & Matsumoto, 1999).

The Cognitively-Guided Instruction (CGI) mathematics project (Carpenter, Fennema, & Franke, 1996; Fennema et al., 1996) focused on improving learning by having teachers examine students' mathematical thinking while completing mathematical tasks. CGI teachers watched video cases of students as they completed the tasks and discussed students' problem-solving processes. After examining the student's approaches to problem solving, teachers described how they could modify their instruction to design tasks that were appropriate to their students' cognitive development. When they returned to their classroom, teachers were expected to pose mathematical tasks, pose questions about students' mathematical thinking, analyze their students' approach to solving

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[1] Tables 2.2, 2.3 and 2.4 are presented at the end of this chapter on pages 44-46.

problems, and use that information to design other appropriate tasks. Data collected from interviews and classroom observations indicated that CGI teachers began to adopt both the beliefs and instructional practices emphasized during the workshops. Researchers also examined student performance and found that students in classrooms where CGI teachers incorporated more appropriate mathematical tasks into their instructional practices scored higher on an assessment of problem-solving ability than students who did not (Carpenter et al., 1996). Further, while students in CGI classes scored comparably to control students initially, students who participated in CGI classes for two years scored significantly higher than students who had never been in a CGI classroom during the project's second year.

CGI was among the first professional development programs to link professional development to student achievement. The project staff developed a computation test and a problem-solving assessment, students were tested annually for three years, and scores were analyzed across teachers. Researchers also examined students' scores based on the length of time that students had been in CGI classrooms. Although the link between professional development and student learning is difficult to warrant due to the myriad factors, evidence tentatively suggests that teacher participation in the project may have improved student learning. In order to document the influence of professional development programs on student learning, it is important to link the instructional practices emphasized during professional development and teachers' enactment of those instructional practices with student learning outcomes that are aligned to those practices.

Teacher-owned

Principle 9 of the APA Work Group's (1997) learner-centered principles indicates that motivation is a key learning influence; motivation is also attributed in other APA principles to learners' beliefs and interests (Principle 7), creativity and curiosity (Principle 8), and background and experiences (Principles 10, 12 and 13). Loucks-Horsley et al. (2003) found that involving teachers in planning and selecting their professional development activities increased both their motivation to participate and the likelihood of classroom application. This pattern has been reported by other researchers who reported that teachers who chose their activities reported greater classroom implementation of than those who did not (Pink, 1992; Pink & Hyde, 1992).

However, ownership of learning can prove problematic: teachers are sometimes unaware of their own knowledge and skill needs (Borko & Putnam, 1995). Teachers surveyed and interviewed have reported that they prefer to participate in activities that can be applied immediately in their classroom over activities designed to develop their content knowledge (Wilson & Berne, 1999). However, learner-centered approaches often require both efforts to refine content and pedagogical content knowledge, as well as conceptual change about mathematics teaching, over an extended period of time (Fennema et al., 1996). Thus, learner-centered pedagogies may prove difficult or impossible to implement immediately without adequate support (e.g. CTGV, 1992; Fishman et al., 2003; Remillard, 2005; Schneider et al., 2005). Professional development programs need to attain a balance between what teachers want (i.e., promote teacher ownership, immediate classroom application) and what they need (i.e., reifying critical connections between teacher content and pedagogical content knowledge and student learning).

The LeTUS project staff developed learner-centered, technology-rich science units for teachers to use with middle school students. In one study, teachers implemented a pre-designed unit with a high degree of fidelity in Year 1. However, teachers reported that they needed additional opportunities to learn about the technology, the science content, and the tasks in order to implement the units effectively (Fishman et al., 2003). Year 2 professional development activities were revised accordingly to increase the time allotted for teachers to work with the content and technology. As a result, teachers reported increased sense of ownership of the units and the professional development program. Subsequent observations indicated that teachers applied the project's learner-centered pedagogy in the LeTUS unit as well as other science units (Fishman et al., 2003).

In the CGI mathematics project, staff provided guidance while teachers designed tasks; teachers designed and "owned" the mathematical tasks to be implemented in their classrooms (Fennema et al., 1996). However, task implementation varied. Some teachers implemented learner-centered tasks appropriate for students' cognitive level of mathematical thinking, while others implemented teacher-centered tasks that were not aligned with students' cognitive levels. The CGI team analyzed the implementation data in light of participants' reported beliefs. Using data from surveys, interviews, and classroom observations in an effort to align teacher's reports of mathematical beliefs to their implementation of CGI's practices, the research team concluded:

> Although the relation between levels of instruction and beliefs appears obvious, it was difficult to compare the relationships because a teacher's beliefs and instruction were not always categorized at the same level, and there was no

> overall pattern as to whether a teacher was at a higher level in beliefs or instruction. There was also no consistency in whether a change in beliefs preceded a change in instruction or vice versa (Fennema et al., 1996, p. 423)

These findings are consistent with previous research indicating the influence of teachers' beliefs on their instructional practices (Cooney, 1985; Franke et al., 1995 as cited in Fennema et al., 1996; Thompson, 1992). The CGI team suggested that teachers' change in practice could be attributed to "owning" the design and the enactment of the mathematical tasks in their classroom. In essence, teachers used their classroom as a "learning laboratory" (Fennema et al., 1996, p. 431).

Teacher ownership is critical to learner-centered professional development, as it increases the relevance of the activities. In the LeTUS project, designing professional development activities based on teacher's feedback led to a significant increase in student learning. The CGI research indicates that professional development needs to address teachers' beliefs that may vary from those advocated by or embodied in learner-centered professional development programs. Research is needed to identify factors influencing teachers' negotiation of their individual learning needs. To this end, we also need to study how professional developers support teachers as they attempt to enact the professional development practices in their classrooms.

Collaborative

According to Hargreaves (1997), learner-centered professional development programs should also develop a "culture of collaboration among teachers" (p. 1306). While some have described teachers as working in relative isolation (Lortie, 1975), contemporary views of knowledge construction suggest that teacher learning can be enhanced by allowing teachers to collaborate with colleagues in professional learning communities (e.g. Darling-Hammond, 1998; Putnam & Borko, 2000; Glazer & Hannafin, 2006). Consistent with APA's 11th learner-centered principle, "social interactions, interpersonal relations, and communication with others all provide opportunities for learning."

Researchers examining successful schools (Little, 1993) and school reform efforts (Bay, Reys, & Reys, 1999; Fullan, 1991) cite the importance of a collaborative environment. In professional development, numerous approaches to supporting collaboration have been advanced. ACOT (Ringstaff et al., 1996; Sandholtz et al., 1997) and CGI projects (Carpenter et al., 1996; Fennema et al., 1996) established collaboration in the workshops between project staff and teachers and also between the teachers themselves. Similarly, Glazer and Hannafin (2006) proposed a collaborative apprenticeship model in which a teacher-mentor guides a peer teacher through technology integration design and planning. Collaborative professional development embodies contemporary views that learning is situated in contexts, a social process, and distributed across activities, individuals and resources (Putnam & Borko, 2000).

The QUASAR project brought university professors, middle school teachers and school administrators together to design and implement learner-centered mathematics instruction consistent with the NCTM standards (NCTM, 1991, 2000). The project staff characterized teacher change and mathematics education reform as a "process that takes advantage of the synergy, support, and motivation supplied when a 'critical mass' of teachers undertakes reform for all students in a given school" (Stein & Brown, 1997, p. 156). QUASAR researchers documented several difficulties middle-school teachers encountered while implementing a learner-centered mathematics curriculum. Initially, teachers experienced problems modifying a traditional mathematics textbook; in subsequent project years, they used a learner-centered, reform-based curriculum but struggled during implementation due to a lack of content knowledge, an incomplete understanding of learner-centered pedagogies, and a district-wide emphasis on skills-based mathematics assessments. Implementation of learner-centered instruction did not improve until the third year, when the district's mathematics coordinator initiated co-planning meetings with the teachers. During their common planning time, the mathematics coordinator co-planned lessons based on the learner-centered curriculum and helped teachers locate materials and plan learner-centered instruction. Over time, the teachers collaborated with one another and rotated the responsibility to find resources and lead brainstorming sessions on ideas for lessons. Gradually, the mathematics coordinator withdrew her involvement, allowing the teachers to continue to collaborate but also have more ownership of their lesson planning. In effect, this provided teachers a collaborative apprenticeship where professional developers provided scaffolds to support the design and implementation of learner-centered instruction (Glazer & Hannafin, 2006).

Sherin and van Es' (2005; van Es & Sherin, 2002) work with video clubs also provided teachers with opportunities to collaboratively reflect on each other's mathematics teaching. By viewing videos together, teachers were able to compare their perspectives on videotaped practices with those of professional developers and peers. Teachers met after school to watch videos of each other's mathematics teaching. Following each video, teachers discussed both the tasks posed and teacher-student interaction, focusing on teacher questioning and students' mathematical thinking. The teachers then returned to their classroom and were charged to modify their teaching based on the pedagogies discussed during the video club. Collaboratively watching and sharing feedback during workshops increased the frequency with which teachers posed learner-centered tasks in their classrooms, facilitated student task completion via questioning, and interacted with students regarding their mathematical thinking and approaches (Sherin & van Es, 2005).

ACOT staff redesigned project activities for delivery in professional development centers located in schools where expert ACOT teachers worked. During the professional development, teachers learned about various pieces of technology, discussed approaches to integrating technology, observed the teaching of model technology-rich lessons, and co-planned and practiced teaching in a technology-rich classroom with the support of ACOT staff and expert teachers (Ringstaff & Yocam, 1994; Yocam & Wilmore, 1994). ACOT teachers also requested school-based support to help implement technology-rich lessons planned during the workshops. The initial peer collaboration *during* professional development was not available to support implementation when teachers returned to their classroom (Ringstaff et al., 1997). Rather than providing school-based support, the project emphasized purchasing equipment, providing professional development workshops, and conducting research.

Opportunities to collaborate are essential if teachers are to design and implement learner-centered tasks in their classrooms. Initiatives where project personnel apprentice teachers in the design and enactment of learner-centered tasks (Glazer & Hannafin, submitted; Stein & Brown, 1997) and teachers collaborate to critique and share ideas about teaching (Sherin & van Es, 2005) show promise. While teachers need school-based support in order to implement learner-centered tasks, collaboration may be neither feasible nor practical in many instances.

Comprehensive

According to the National Science Foundation’s meta-analysis of Local Systemic Change through Teacher Enhancement Initiative, after 30 hours of professional development shifts in teachers’ practice and impact on student learning should become apparent (Banilower, Boyd, Pasley, & Weiss, 2006). While this finding seemingly contradicts numerous multi-year studies in which the impact of professional development on teachers’ practices and student learning does not appear until at least the second year (Fennema et al., 1996; Fishman et al., 2003; Silver & Stein, 1996; Stein & Brown, 1997), the disparity may be associated with the nature of the changes expected or required. To the extent professional development reifies, extends, and is aligned with teachers’ existing beliefs and practices, less time and support may be needed to influence practice and student learning. To the extent substantial differences exist between current and professional development domain, epistemological and pedagogical knowledge, school culture, beliefs and practices, substantial time and support may be required (Fullan, 1991; Loucks-Horsley et al., 2003).

Learner-centered professional development programs need to provide sustained and comprehensive support for teachers as they enact new instructional practices in their classroom (Hawley & Valli, 1999; NPEAT, 2000a). Teacher learning authorities advocate multi-year programs (Richardson, 1990) that include a variety of learning opportunities (Loucks-Horsley et al., 2003); however, most professional development programs are limited in funding and rarely sustained (Garet, Porter, Desimone, Briman &

Yoon, 2001). Further, professional development is most effective when it is supported by and aligned to reforms and policies at the school, district and state levels (Fullan, 1995). Clearly, such support requires significant time and resources from professional developers and school personnel (Orrill, 2001; Richardson, 1990)

The LeTUS project (Fishman et al., 2003; Kubitskey et al., 2005), was part of a seven-year science reform effort between university researchers and an urban school district (Fishman et al., 2003). While LeTUS teachers enacted the curriculum at a high fidelity, teachers reported discomfort using the technology, specific instructional practices and their role as facilitators during the implementation. LeTUS personnel redesigned the professional development, so that workshops in year two focused more on increasing teacher's knowledge of content and comfort using technology and facilitating student's completion of the learner-centered tasks. In addition to teachers' enactment remaining high, student learning, which had only increased slightly in year one, improved significantly during the second year.

In the CGI project, teachers spent the first year learning about the project's rationale and the goal of supporting student's learning through learner-centered mathematical tasks and questioning strategies. While teachers posed tasks in their classroom, they were simultaneously learning how to design, support and enact associated practices. Thus, some teachers immediately modified their practices, while others did not substantially alter their teaching until year two. Further, analyses of student achievement data indicated that significant increases in student learning typically did not occur until the year following a significant change in instructional practices. Thus, teachers who modified practices during year one observed improvements in student achievement at the end of year two; those who did not change their practices until year two observed increases in student achievement at the end of year three (Fennema et al., 1996). Research is needed to examine the impact of learner-centered professional development programs across time. These studies can give insight to the amount of time in various professional development activities needed to effectively support teachers' implementation of the instructional practices emphasized in these programs.

Comprehensive professional development initiatives also call for numerous school personnel to be involved in the implementation of learner-centered curriculum. Research is needed to clarify both time and support needed to sustain implementation of learner-centered curriculum. After these factors have been identified, studies should be conducted to identify how professional development programs can influence these factors in a way that will support the implementation of learner-centered curriculum.

Content and pedagogically-based

Professional development on specific content and content-specific instructional practices has been found to change teacher practice and improve student learning (Garet et al., 2001; Kennedy, 1998). Desimone, Porter, Garet, Yoon, and Birman (2002) also found that teachers who participate in activities that focus on specific content or pedagogy (e.g., inquiry-based science activities, mathematical investigations, product-oriented history projects) reported higher adoption rates of associated instructional practices. According to an NCES survey of nearly 1,500 teachers, over half reported using standards-based activities to a great extent in their classroom (USDoE, 1998); of those who reported using standards-based classroom practices, 65% had participated in professional development focused on standards-based instruction.

Teachers also benefit from opportunities to develop content knowledge in their teaching field (Loucks-Horsley et al., 2003). This is especially evident in mathematics, where teachers' content knowledge and pedagogical content knowledge have been empirically linked to student learning (Hill, Rowan, & Ball, 2005). According to *APA Learner-Centered Principles* (APA Work Group, 1997), learning is most effective when learners construct meaning from information and experience (Principle 1), and is enhanced through guidance (Principle 2) and increased motivation (Principle 9). Learners, in turn, are motivated by activities aligned to their interests (Principle 7) and their personal experiences (Principles 10, 12 and 13). To this end, teachers need sustained opportunities to engage domain content, experience and adapt pedagogies, and enact and refine learner-centered classroom-relevant activities.

One approach to developing content knowledge involves having teachers participate as learners in tasks that resemble those they will implement in their classrooms (Loucks-Horsley et al., 2003). Professional development designed to support technology-rich, learner-centered tasks should give teachers the opportunity to use technology to complete these tasks while professional developers model the practices to be enacted in their classrooms. Further, these experiences should be customized to provide opportunities for teachers to consider how to implement these tasks with their own students. Hence, professional developers need to design and model tasks that deepen teachers' content and pedagogical content knowledge and will benefit their classroom teaching (Hawley & Valli, 1999).

The LeTUS project focused on integrating technology-rich, learner-centered science activities in middle school classrooms. LeTUS units were designed by the project staff and allowed students to use technology to address a driving question on a real-life scenario by gathering, examining, and synthesizing information. During professional development, teachers first engaged with the curricular materials as learners, while the LeTUS project staff modeled how to use technology, questioned teachers and led discussions that helped unpack the science content. In essence, the LeTUS staff explicitly mimicked the instructional practices that they wanted the teachers to enact in their own classroom (Blumenfeld, Fishman, Krajcik, Marx, & Soloway 2000). Upon completing the workshops, teachers reported feeling prepared to integrate LeTUS units into their teaching.

Unlike findings from the *Jasper* project, where some teachers used technology-rich learner-centered activities in a didactic manner (CTGV, 1997), most LeTUS units were enacted as modeled in the learner-centered professional development activities. Apart from minor adaptations, such as shortening the length of discussions, classroom observations indicated that the units were implemented very closely to their intent (Fishman et al., 2003). While high fidelity enactment could be attributed to the teachers' willingness to employ constructivist-based instructional practices, researchers suggested that fidelity was also influenced by the depth and detail of the supporting materials (Fishman et al., 2003; Kubitskey et al., 2003). Teachers were given lesson plans, student worksheets, instructional materials and technology resources, thus providing maximum scaffolding and minimal flexibility for unit modification.

Despite the extensive support provided to LeTUS teachers, teachers still reported difficulties with implementation related to limited understanding of both associated science content and technology. Since workshop activities were not designed to develop content knowledge, some teachers lacked adequate domain knowledge. Thus, while implementing LeTUS activities— answering students' questions, and facilitating the students' work—teachers lacked the requisite content knowledge needed to effectively model, question, and support students' investigations during the unit (Kubitskey et al., 2003). Similar findings were found in mathematics where Ma (1999) found that American elementary mathematics teachers' lack of content knowledge led them to be more didactic. Further, in cases where teachers attempted to implement learner-centered instruction, they struggled to lead discussions and answer students' questions about the mathematics that was embedded in the tasks.

The CGI project (Carpenter et al., 1996; Fennema et al., 1996) also emphasized knowledge of content and pedagogy. Participating teachers completed mathematical tasks and learned how specific tasks were aligned to stages of children's cognitive development. Rather than focusing on developing teachers' content knowledge, the CGI workshops prepared teachers to attend to their students' work and mathematical thinking. As teachers enacted tasks with their own students they connected workshop constructs and pedagogies related to children's mathematical thinking with their students' experiences. While attempting to implement tasks, teachers were increasingly sensitized to their students' success and began posing more tasks appropriate to student's cognitive level (Fennema et al., 1996). During the CGI project, teachers both observed models of tasks being enacted and worked with mathematical tasks prior to implementing them in their classrooms.

Reflective

Reflection has been identified as critical to teachers' learning activities (Fernandez, 2003; Schon, 1985) and learner-centered professional development. Professional development literature is replete with recommendations that professional development focus on teachers' everyday practice (Ball & Cohen, 1999; Loucks-Horsley et al., 2003), be situated in teachers' work (Putnam & Borko, 2000), and allow teachers to examine specific instances of teaching in their own classroom (Recesso, Hannafin, Deaton, Shepherd, & Rich, in press). However, professional development efforts have been criticized for focusing on activities and resources that have little connection to classroom practice (Guskey, 2000; Little, 1993).

Reflective activities both help teachers to connect professional development activities to their classroom practice and enable researchers to examine teacher practice during and after professional development. In recent years, video and computer-based technologies have been used to facilitate teacher learning (e.g., Marx et al., 1998; Recesso et al., in press; van Es & Sherin, 2002). These technologies allow teachers to watch, examine and critique their own classroom practice, and identify specific instances of effective teaching practices as well as instances where approaches can be refined (Recesso et al., in press).

Sherin and van Es (2005; van Es & Sherin, 2002) brought middle school teachers together monthly to view, discuss, and analyze video examples of their mathematics instruction. Teachers videotaped their teaching, then used a computer-based tool (Video Support Analysis Tool: VSAT) to study their approaches and discuss instances where the students interacted with mathematics content, the teacher, or classmates. Each video was first analyzed in a group, which enabled teachers to share perspectives on the tasks posed and teacher-student interactions. After the discussion, the teacher of the lesson used the VSAT tool to reflect on individual teaching and discuss potential modification in their future instruction. After reflecting, teachers attended more frequently and specifically to students' mathematical thinking and mathematics in the lesson activities. Further, based on follow-up classroom observations, the researchers reported increasingly student-centered pedagogy, as teachers gave students opportunities to communicate their mathematical ideas (Sherin & van Es, 2005). They recommended further examination as to differences in teachers' use of video and the influence of video reflection on their practice (Sherin & van Es, 2005).

While reflection has the potential to impact teacher's practice, the manner in which it is instantiated, the information available, and the timing and frequency appear to influence how (or if) practices are changed. Research is needed to examine the influence of both the activities and evidence (e.g. lesson plans, student work samples, student assessment data, video clips) used to reflect on reflect on practice. Further, as in the case of the video clubs project (Sherin & van Es, 2005; van Es & Sherin, 2002), research is needed to determine how best to scaffold the reflective process to help teachers examine their teaching practice.

Researchers and professional developers have documented evidence to suggest uncertainty in exactly what, and how much, learner-centered activity is actually implemented following professional development (Guskey, 2000; Loucks-Horsley et al., 2003). Some teachers report epistemological conflicts with learner-centered activities, resist implementing these activities, and do not experience the conceptual change requisite for implementation (Franke, Carpenter, Levi, & Fennema, 2001). Others intend to employ learner-centered activities but compromise them by providing pedagogically incompatible procedures (e.g., CTGV, 1997; Peterson, 1990; Wilson, 1990). Finally, teachers may espouse that they are implementing learner-centered activities, but observations of their teaching prove otherwise (Peterson, 1990).

Professional development research is needed to identify characteristics that influence both teacher practices and student learning. Following his synthesis of recommendations for professional development, Guskey (2003) concluded that despite the myriad of research studies and recommendations for professional development programs, considerable uncertainty remains about what actually works. In the following section, I adapt Guskey's (2000) framework to frame needed research on learner-centered professional development programs.

Implications for Research

LCPD research implications are organized according to Guskey's (2000) five levels: participant reaction, participant learning, organization support and change, participant use of new knowledge and skills, and student outcomes.

Participant reactions

In LCPD programs, teachers' reactions are useful in assessing the extent to teacher perceive professional development activities as relevant, effective and useful; they also serve as indicators of the likelihood teachers intend to apply LCPD knowledge and skills in their classroom (Loucks-Horsley et al., 2003). More importantly, teachers are both active participants and co-designers in LCPD; feedback regarding their perceptions can enable design adaptations that increase the likelihood and success of subsequent implementation (Guskey, 2000). In the LeTUS project, for example, teachers reported limited knowledge of content and technology, insufficient time to implement the materials, and a need for additional school-based support after the first year of the project (Fishman et al., 2003; Schneider et al., 2005). Left unaddressed, these concerns presented significant barriers to both the effectiveness and sustainability of the classroom implementation. Based on survey and interview data from participants, the project staff was able to formatively evaluate and modify the activities for Year Two of the project.

While gauging participants' reactions is useful in evaluating perceptions of learner-centered professional development programs, it is insufficient to assess professional development effectiveness or implementation. Participant reactions provide professional developers with a limited scope of their program's impact and can provide misleading information about the success of the program, simply because participants reported enjoying it (Guskey, 2000). Self-report data have been characterized as subjective and often inaccurate (D. Schacter, 1999); participants have been found to overstate their intentions to implement nuanced learner-centered activities more extensively and pervasively than evident in their actual practices (Buck Institute for Education, 2002; Mullens, 1998; Ravitz, 2003). Professional development research needs to extend beyond participants' reactions and self-reported data (Borko, 2004; Georgia House, 2005) to include evidence of learner-centered classroom implementation.

Participant learning

A primary goal for LCPD is to provide teachers with opportunities to develop knowledge and skills to positively impact student learning. Consistent with learner-centered instruction, teachers "own" the focus of their professional development. LCPD can emphasize developing content knowledge, pedagogy, and/or use of instructional resources. Hence, individual teachers focus to a greater or lesser extent on different elements of professional development. In LCPD involving significant content understanding, epistemological beliefs and practices, technology integration, and associated practices, it is important to establish the extent to which critical knowledge and skill has been learned. To this end, research is needed to identify potential gaps between the knowledge and skills deemed fundamental to professional development and knowledge and skill gained by individuals during LCPD.

Recently, for example, researchers have developed tests to measure teacher's content knowledge needed for teaching reading (Phelps & Shilling, 2004) and mathematics (Hill et al., 2005). These tests attempt to examine content knowledge in the context of teaching, and to provide evidence of teachers' knowledge likely to influence the implementation of learner-centered tasks. LCPD professionals and researchers may use similar assessments to better identify teacher's initial needs for professional development activities as well as to assess a program's impact on teacher's knowledge for teaching.

Further, we need to examine teachers' knowledge of pedagogy, technology and other resources associated with learner-centered instruction. LCPD supports teacher's learning of how to integrate those resources into the classroom to support student learning; to do so in a manner consistent with learner-centered epistemology, conceptual change may be required regarding the nature and locus of knowledge (Richardson, 1990) as well as the methods through which teachers engage students (Hawley & Valli, 1999).

Research is needed to examine how LCPD influences both teachers' beliefs and skills related to learner-centered teaching with technology.

In addition, portfolios containing lesson plans and implementation artifacts can include student learning evidence, but they often fail to adequately document how learner-centered principles are enacted in classrooms or their impact on student learning (Guskey, 2000). While examinations of teachers' knowledge are useful, these methods give little detail about how teachers actually enact learner-centered tasks in their classroom.

The effectiveness of learner-centered tasks is substantially influenced by the teacher's role during enactment. Teachers are charged with posing worthwhile tasks, equipping students with appropriate resources and then facilitating learning during the task (McCombs & Whisler, 1997). Teacher's actions during the enactment of learner-centered tasks have been empirically connected to their content knowledge (Kubitskey & Fishman, 2005; Ma, 1999), knowledge for teaching (Stein, Grover & Henningsen, 1996) and knowledge of how to integrate resources such as technology into their classroom (Ertmer, 1999). Therefore, LCPD research must consider how teachers carry the various types of knowledge from LCPD into their classroom.

Organization support and change

In order to become collaborative and be comprehensive, LCPD programs emphasize classroom implementation support—support rarely available or provided in routine professional development initiatives. Attempts to study the impact of LCPD on the school and district resources have proven problematic due to the complex and numerous variables involved. These variables include access to resources, administrative support, school policies, and building-level support. Professional developers (Hawley & Valli, 1999; NPEAT, 2000a) and educational reform researchers (Bay et al., 1999; Fullan, 1991) have underscored the importance of support from leaders at the school building and school district levels. In both the QUASAR (Stein & Brown, 1997) and the LeTUS projects (Fishman et al., 2003), learner-centered task implementation was directly influenced by the relationships among professional developers, researchers, teachers, school administrators and district-level personnel. At one middle school in the QUASAR project, the implementation of learner-centered mathematical tasks did not improve until the teachers received support from their district mathematics coordinator (Stein & Brown, 1997).

Further, professional development research has suggested the presence of conflicting or contradictory goals between and among teachers, professional developers and school-district personnel (Fullan, 1995; Loucks-Horsley et al., 2003). In the QUASAR project, teachers were encouraged in their professional development to use learner-centered approaches to teaching, but their district's emphasis on increasing student achievement on skills-based assessment led them to teach algorithms to support the completion of computational tasks. Teachers recognized competing goals and teaching methods, and did not enact learner-centered tasks until concerns about competing priorities and the need for in-school support were addressed. Further study of the support anticipated, needed, and provided to implement learner-centered activities and tasks is needed to assess both the implications of adopting learner-centered curriculum and pedagogy on school resources as well as its impact on the school, school district and support organizations.

Participant use of new knowledge and skills

Learner-centered professional development aims to support teachers' enactment of learner-centered tasks (NPEAT, 2000a); research is needed to examine the nature of, and extent to which, LCPD knowledge, skills, and practices carry over to implementation in everyday classrooms. In situ data from classroom observations and videos of teacher's classrooms can provide rich evidence and document the extent and the manner in which teachers design and implement the learner-centered tasks emphasized during professional development.

Video technologies allow researchers to capture evidence of teacher's enacted practices. Teachers are influential during learner-centered instruction and must facilitate learning during implementation by modeling processes, asking questions that probe student thinking and providing scaffolds to guide learning (McCombs & Whisler, 1997). Video-based data allow LCPD researchers to document and analyze the enactment of learner-centered tasks. Researchers can identify specific instances in which teachers demonstrate strategies that are likely to influence student learning.

Video can also be used to support LCPD program implementation, such as using classroom observations to formatively evaluate and modify LCPD programs (Borko, 2004). For example, teachers in the ACOT project struggled with the classroom logistics, such as troubleshooting with technology, facilitating a learner-centered, technology-rich task and managing a class in the midst of completing tasks (Sandholtz et al., 1997). As a result of these observations, the ACOT staff developed centers where teachers could observe exemplar teachers as they posed learner-centered tasks to their students. After such observations, teachers indicated greater comfort enacting learner-centered tasks and reported fewer problems posing tasks to their students.

In addition, research is needed to examine the relationships between and among teacher's intended and espoused teaching practices. Previous studies have suggested significant shifts in self-reported attitudes, beliefs and practices (e.g. Garet el al., 2001; Loucks-Horsley et al., 2003; Sandholtz et al., 1997). Despite optimistic indications of intentions to implement, and self-reports of changes in teaching practices following professional development, few researchers have corroborated corresponding changes in classroom practices (Buck Institute, 2002; Ravitz, 2003; Wilson & Berne, 1999). Research is needed to link teacher intentions to enact learner-centered tasks, self-evaluations of classroom enactments, and actual classroom practice. The alignment or disconnect between these three constructs may provide important insights into both how to scaffold teacher learning and support implementation as well as improved ability to identify the presence of LCPD characteristics in classroom practice.

Student learning

LCPD programs must effectively prepare teachers to improve student learning. Hence, LCPD research should examine the impact of the program on student learning outcomes. Historically, few have examined the impact of professional development on student learning outcomes (Guskey, 2005); recently, however, the need to document the influence of professional development on student learning has grown significantly (Borko, 2004; NCLB, 2002). Both educators and policymakers seek evidence confirming or disproving assumptions as to the impact of teacher professional development on student learning (NCLB, 2002; Guskey, 2005). While some researchers have attempted to link professional development to student achievement (e.g. CTGV, 1997; Fennema et al., 1996; Kubitskey et al., 2003; Sandholtz, et al., 1997), such efforts are rare and, unfortunately, often inconclusive.

Due to the significant ongoing investment of time, effort, and resources to support LCPD, and assumptions as to improvements in student reasoning and learning associated with learner-centered instruction, documentation of student impact is especially important (Georgia House, 2005; NCLB, 2002). Recently, researchers have attempted to attribute increases in statewide achievement scores or self-created measures of student learning to teachers' participation in professional development (e.g. Bay et al., 1999; Fennema et al., 1996; Fishman et al., 2003; Fogleman & McNeil, 2005; Knezek & Christensen, 2004). While these methods attempt to link LCPD to student learning, the measures often are not aligned to either LCPD or the learner-centered practices that teachers enacted in their classroom. In instances where evidence suggests that student learning improved, justification for associating such gains to LCPD has proven elusive (Ringstaff et al., 1997; Knezek & Christensen, 2004).

Linking professional development with student learning. In many cases, professional development projects provide only a cursory examination of participants' self-reported feelings and impressions of the professional development (Guskey, 2000; Guskey, 2005). Recent legislative mandates to increase the accountability of professional development programs as well as the rigor of evaluations have contributed to the desire to link professional development to student learning (Georgia House, 2005; NCLB, 2002). Efforts to link LCPD to student learning often attempt to demonstrate a return-on-investment (e.g., time, money and resources expended in proportion to improvements in student learning).

In order to link LCPD's impact on teacher learning and student learning, we need to align associated teacher learning from LCPD and classroom enactments of learner-centered tasks with student performance measures appropriately aligned with, and sensitive to, knowledge, skills, and processes that are associated with learner-centered tasks. However, definitive attributions of impact have rarely been documented in either professional development generally or LCPD in particular. Claims as to the impact of LCPD are largely anecdotal and baseless in the absence of evidence of classroom enactment and appropriately aligned measures of student learning. In situ data from teachers' classrooms may provide insight into how participants enacted the knowledge and skills learned during the professional development (*enacted practices)* as well as the tasks that the teacher had planned (*intended practices)* (Remillard, 2005). These data may strengthen claims of LCPD's influence on the enactment of learner-centered instruction.

Researchers examining student learning outcomes often report student learning on norm-referenced, standardized tests (NCES, 2000, 2004; Wenglinsky, 1998). While improving student achievement on these assessments is valuable, measures of student learning that are aligned with the goals of LCPD and associated classroom practices may provide compelling evidence of the link among teacher learning, classroom enactment and student learning. The CGI and the LeTUS projects both used assessments of student learning that aligned to their professional development. Ultimately, the type and nature of the formative evidence of student learning can become increasingly sophisticated as their predictive properties related to student learning on formal measures are established.

In addition to efforts that link LCPD to student learning, it is also important to examine student learning on measures that are influenced indirectly by learner-centered instruction. For example, researchers in the *Jasper* project examined student learning on both computational and problem solving skills in mathematics (CTGV, 1997). The researcher's goal was to examine how learner-centered instruction influenced student performance on learner-centered tasks as well as basic computational tasks. When compared to non-Jasper classrooms, *Jasper* students scored significantly higher on measures of problem solving and comparable to non-Jasper students on measures of computational skills. Thus, researchers provided evidence that the use of learner-centered tasks improved problem solving skills without adverse effects on computational skills (CTGV, 1997).

Conclusion

Clearly, we need to more closely examine how to best support classroom implementation of learner-centered tasks and the influence of these tasks on student learning. Previous research has identified numerous barriers that teachers confront as the attempt to enact learner-centered tasks in their classroom. Research is needed to identify and refine LCPD components that influence teacher learning, classroom implementation of learner-centered tasks, and the impact of learner-centered tasks on student learning.

Table 2.2: Characteristics of Learner-Centered Professional Development (LCPD) Programs

Characteristic	Literature on Teacher Learning and Professional Development	APA Learner-centered Principles (APA Work Group, 1997)
Student-focused	Professional development should focus on analyzing the gap between (a) goals and standards for student learning and actual student performance and (b) prepare teachers to bridge that gap (Hawley & Valli, 1999).	The learning of complex subject matter is most effective when learners construct meaning from information and experience (Principle 1). The successful learner, over time and with support, can create meaningful, coherent representations of knowledge (Principle 2).
Teacher-guided	Professional development should involve teachers in selecting the content of professional development programs and, if possible, give teachers choices about learning activities (Hawley & Valli, 2000; NPEAT, 2000a).	Individual's learning is influenced by their motivation (Principle 9). An individual's motivation is influenced by their beliefs and interests (Principle 7), the learner's creativity and curiosity (Principle 8), and their background and experiences (Principles 10, 12 and 13)
Collaborative	Professional development should allow teachers to collaboratively work together (NPEAT, 2000a; Sparks & Hirsch, 2000) and develop the problem solving skills needed to teach effectively (Putnam & Borko, 2000).	Social interactions, interpersonal relations, and communication with others all provide opportunities for learning (Principle 11).
Comprehensive	Professional development should be connected to a comprehensive change process focused on improving student learning (Hawley & Valli, 1999).	The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge (Principle 2).
Content and pedagogically-based	Student learning can be influenced by increasing teachers' content knowledge (Ball, Lubienski, & Mewborn, 2001), pedagogical content knowledge (Marzano, Pickering & Pollock, 2001) and by examining how students learn (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996).	The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience (Principle 1). The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge (Principle 2). Individual's learning is influenced by their motivation (Principle 9).
Reflective	Professional development should allow teachers to reflect on evidence of their teaching: (a) student work samples and (b) artifacts from their own teaching (Hawley & Valli, 1999; NPEAT, 2000a).	The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience (Principle 1). Assessment is an integral part of the learning process (Principle 14).

Table 2.3: Examples of Professional Development Programs that Exhibit Learner-Centered Characteristics

Program	Goal	Characteristics	Description
Cognitively Guided Instruction (CGI) (Carpenter, Fennema, & Franke, 1996; Fennema et al., 1996)	To improve teachers' mathematics instruction in elementary grades by examining students' mathematical thinking.	Student-focused	Teachers examined student work samples while solving mathematical tasks.
		Teacher-guided	Teachers wrote mathematical tasks appropriate for their students. The teachers then returned to workshops to discuss their tasks and refine them for future use.
		Collaborative	Teachers collaborated in workshops to solve tasks, discuss tasks and design tasks to use with their students.
		Comprehensive	Teachers from the same school district participated in the project over a few years.
		Content and pedagogically-based	Teachers learned about types of mathematical tasks, how to match tasks with students' cognitive development, and designed tasks to use with their own students.
		Reflective	Teachers examined student work samples and videotapes of students solving tasks. Teachers reflected on their own students solving the tasks that they wrote.
Center for Learning Technologies in Urban Schools (LeTUS) (Blumenfeld, Fishman, Krajcik, Marx, & Soloway 2000; Fishman, Marx, Best, & Tal, 2003; Schneider, Krajcik, & Blumenfeld, 2005)	To improve students' learning in middle grades science through the use of technology-rich inquiry-based science units.	Student-focused	The units were designed by project staff to teach science standards in a constructivist-based, open-ended manner.
		Teacher-guided	Year two activities addressed the concerns that teachers expressed at the end of year one.
		Collaborative	Teachers supported each other in workshops during activities and in schools while implementing the units.
		Comprehensive	This project was an on-going partnership between the school district and the university to integrate technology-rich, inquiry-based teaching.
		Content and pedagogically-based	Teachers' activities focused on science content they were teaching and constructivist-based pedagogies.
		Reflective	Teachers spent time during the workshops reviewing and reflecting about their implementation of the units.
Apple Classrooms of Tomorrow (ACOT) (Ringstaff, Yokam, & Marsh, 1995; Sandholtz, Ringstaff, & Dwyer, 1997)	To improve student learning in K-12 classrooms through the integration of technology into classrooms.	Student-focused	Teachers designed technology-rich units to address specific content that they taught.
		Teacher-guided	Teachers selected what technologies they were going to integrate, what subjects they were going to focus on and what activities they were going to use with their students.
		Collaborative	Teachers from the same school attended professional development workshops and worked together to plan activities.
		Comprehensive	Teachers participated in this project over a period of years and received resources and professional development to support their teaching.
		Content and pedagogically-based	Teachers learned about best practices for teaching with technology (e.g. collaborative work, inquiry-based projects).
		Reflective	Teachers conducted e-mail and face-to-face reflections with project staff.

Table 2.4: Research findings related to Learner-Centered Professional Development

Program	Goal	Data Sources	Findings
Cognitively Guided Instruction (CGI) (Carpenter, Fennema, & Franke, 1996; Fennema et al., 1996)	To improve teachers' mathematics instruction in elementary grades by examining students' mathematical thinking.	• Classroom observations • Interviews • Student tests (computation and problem solving)	• Teachers were observed exhibiting CGI-based instructional practices. • Teachers reported their beliefs about mathematics learning became more aligned with CGI. • Student achievement increased at different rates on a problem solving test. • Student achievement remained constant on the computation test. • Students who spent two years or more with CGI teachers scored higher on Problem Solving tests. • Student achievement scores on a problem solving test were significantly greater than control classrooms after using CGI-based instructional practices.
Center for Learning Technologies in Urban Schools (LeTUS) (Blumenfeld, Fishman, Krajcik, Marx, & Soloway 2000; Fishman, Marx, Best, & Tal, 2003)	To improve students' learning in middle grades science through the use of technology-rich inquiry-based science units.	• Pre and post-tests • Surveys • Focus-group interviews • Observations of workshops and classrooms	• Teachers reported being more prepared to support students' work with the units. • Teachers were observed using activities from the professional development regularly in their classroom. • Students' post-test scores were slightly higher than the pre-test scores in year one of the project. • Students' post-test scores were significantly higher than the pre-test scores in year two of the project.
Apple Classrooms of Tomorrow (ACOT) (Ringstaff, Yokam, & Marsh, 1995; Sandholtz, Ringstaff, & Dwyer, 1997)	To improve student learning in K-12 classrooms through the integration of technology into classrooms.	• E-mail reflections • Interviews • Classroom observations • Audio-taped lessons	• Teachers reported using the learner-centered activities that were included in the professional development materials. • Teachers reported that students were more motivated to complete activities and learn content that was taught using technology. • Teachers were observed doing more facilitating in their classroom and using less traditional instructional approaches. • Students in ACOT classrooms did not score higher on nation-wide standardized tests.
Video club project (Sherin and van Es, 2005; van Es & Sherin, 2002)	To improve teachers' capacity to notice classroom interactions and attend more to students' thinking	• Interviews • Classroom observations • Observations of workshops	• Teachers made more comments about students' mathematical thinking. • Teachers made more specific comments about students and the mathematics that they were doing. • Teachers' instruction included more opportunities for students to communicate their ideas about mathematics

Chapter III

METHODOLOGY

Typically, professional development researchers report their findings in terms of survey and interview data (Guskey, 2000). While these are necessary to examine participants' perceptions about their learning experience, these data alone are not sufficient to gauge the impact of professional development. In Georgia, the *A Plus Education Reform Act of 2000* (Georgia House of Representatives, 2000) mandates that, "Staff and professional funds shall be used for activities that enhance the skills of certificated personnel and directly relate to student achievement." In order to understand the impact of professional development programs, evidence about teacher's classroom practices must be examined.

This interpretive study examined the extent to and manner in which teachers enact the activities and practices emphasized during learner-centered professional development (LCPD) in their instruction. Further, the study aimed to describe how artifacts of student understanding are shaped by teachers' enactment of instructional practices stressed during professional development. The participants took part in a professional development program designed to prepare them to teach mathematics in a more investigative way, integrate appropriate resources (manipulatives and technology) into their mathematics classroom, and attend more closely to their students' mathematical thinking.

Three research questions guided the study:

1. *To what extent (and how) do teachers enact the practices emphasized in a learner-centered professional development program during their mathematics teaching?* While teachers often report that professional development has helped them information is rarely collected about how teachers infuse these concepts into practice within their classroom (Guskey, 2000, 2005). The study used classroom observations and video-recorded lessons to determine how participants utilize LCPD instruction.
2. *How do teachers' enactments of the practices emphasized during a learner-centered professional development program compare with their espoused and intended practices?* A gap exists between both professional development practices and activities implemented in typical classroom settings, as well as between teacher beliefs about their practices and evidence of *in situ* classroom pedagogy (e.g., Buck Institute, 2002; Peterson, 1990; Ravitz, 2003). While teachers report that they intend to implement the practices emphasized during professional development, there is often little evidence of application within the classroom. This study examined data from classroom observations, video-recorded lessons, and semi-structured interviews to compare teachers' espoused (what they believe they do), intended (what they plan to do), and enacted (what they actually do) practices in their mathematics classroom.
3. *How does evidence of student understanding reflect their teacher's enacted practices?* In order to understand the link between teacher practices and student learning, the following must be examined: the relationships among professional

development programs, teacher enactment of the professional development content, and student learning (Guskey, 2000). To achieve this, I recorded field notes about how students' mathematical understanding was represented during implementations.

Participants and the Research Site

Purposeful selection. I used criterion sampling, a type of purposeful sampling (Patton, 2002) to select two participants for this study. Purposeful sampling enables the researcher to "learn a great deal about issues of central importance to the purpose of the research" (Patton, 2002, p. 46). The criteria for selecting participants included a) participants' self-reports about what they hoped to learn during their professional development and b) participants' self-reports that they intended to frequently enact the professional development's emphasized instructional practices in their classroom. The data sources for selection were teachers' responses on the participant information sheets (Appendix A) and my own observations and field notes during the first four days of workshops (August 2-4 and August 30, 2005).

Participant recruitment. While recruiting participants for this study I encountered many problems. First, only 12 of the expected 24 teachers attended the first three days of workshops. I wanted to select participants who had attended all of the workshops, since they would be more likely to enact the professional development practices before those teachers who missed the first few days. By examining the participant information sheets and observing participants, only three of those twelve teachers showed a sincere interest in regularly enacting the professional development's emphasized instructional practices throughout the year. Shantel, a fifth grade teacher, agreed to participate. The second teacher declined since his classroom was “full of behavior problems.” The third teacher was involved with two other intense professional development projects and spoke with the project staff about being overwhelmed and possibly too busy to participate throughout the whole year. At the request of the professional developers, I did not ask her to participate.

After the fourth day of workshops on August 30th I decided to expand my pool to include the 12 teachers who had missed the first 18 hours of workshops under the condition that they met my original criteria and attended the make-up sessions for the workshops that they missed. However, 7 of the 12 teachers who missed the first three days were first or second-year teachers. I did not consider them, because I suspected that they would spend the year learning the curriculum, rather than being open to incorporate the professional development practices into their teaching.

On September 15, I drove to Shantel’s school. She wanted me to observe her mathematics classroom without a video camera the first time to ensure that I was still interested in studying her and that students were comfortable with having someone observe them during class. During the visit, I expressed to Shantel the need for one to two more teachers for my study. After the observation she introduced me to Keisha, a fourth grade teacher who had missed the first 3 days of workshops, but had attended the 4th day and one of the make-up sessions. I spoke with Keisha about her reaction to the professional development. She reported that she was interested in using more technology and problem solving in her classroom and that she could see herself using the professional development instructional practices frequently. I invited Keisha to participate in the study and she agreed. That same day, Shantel reintroduced me to

Beatrice, a third grade teacher who had attended the first four days of workshops. Beatrice asked me if she could participate as well. Beatrice was not initially chosen since she reported discontent to being “drafted” by her principal to participate in the program. During this conversation, though, Beatrice reported to me that she was interested in enacting some of the instructional practices in her classroom and that she would like to be included in the study.

However, two weeks later Beatrice withdrew from my study after her first enactment. During the lesson, half of her students were seated off camera since they didn’t have permission slips signed. Those students repeatedly got out of their seat and created classroom management issues. After the lesson, Beatrice apologized for her students’ behavior and asked that I not include her, leaving only Keisha and Shantel as participants.

Both participants reported that they were interested in implementing the professional development practices in their classroom frequently. Both teachers had integrated technology into their classroom, but the technology was limited to websites used to develop students’ computational skills. I suspected that Shantel would be interested in implementing tasks immediately, while Keisha, who had missed the first 18 hours of the professional development, would need more time during the professional development prior to implementing tasks. Due to this, I observed Shantel primarily during the fall, and delayed my observations of Keisha until she had spent more time in the professional development project.

Research Site

Both Keisha and Shantel taught at an urban elementary school (grades K-5) that was situated in the downtown area of a city in the southeastern United States. Table 3.2 summarizes demographic and student achievement information for the participants' school. During the 2004-2005 school year, 95% of the school's 365 students qualified for free and reduced lunch. The students were primarily African-American (79%), while the rest were Caucasian (19%), and Hispanic or Asian (2%).

Table 3.1: Demographic Information for the Research Site

Characteristics	
Percent of students on free and reduced lunch	95%
Ethnicity (2004-2005 School Year)	African-American:79% Caucasian: 19%
Percent of students scoring below proficient on 2003-2004 4th Grade CRCT test	60% *****
Percent of students scoring below proficient on 2004-2005 4th Grade CRCT test	38% *****
***** Below average for students in Georgia as well as other schools in their school district	

The school had met Adequately Yearly Progress (AYP) every year. While scores on the mathematics Criterion-Referenced Competency Test (CRCT) were still low, they had made considerable progress between the 2003-2004 and 2004-2005 school years (Georgia Department of Education, 2005). Both participants attributed this progress to various district-wide initiatives that have been led by the district mathematics coordinator.

TIM: A Case of Learner-Centered Professional Development

Technology Integration in Mathematics (TIM) was chosen as the professional development program for this study because it focused on components aligned with the goals of learner-centered professional development (LCPD). Table 3.2 aligns LCPD characteristics with components of TIM.

Table 3.2: Alignment of TIM to Learner-Centered Professional Development (LCPD)

LCPD Characteristic	Description of Characteristic	Components of the TIM Project
Student-focused	Professional development should focus on analyzing the gap between (a) goals and standards for student learning and actual student performance and (b) prepare teachers to bridge that gap.	• Teachers used video and written cases to deepen their understanding of students' mathematical thinking. • Teachers co-planned with project staff and implemented technology-rich mathematical tasks that address the state mathematics curriculum and their students' needs.
Reflective	Professional development should allow teachers to reflect on evidence of their teaching: (a) student work samples and (b) artifacts from their own teaching.	• Teachers used the Video Analysis Tool (VAT) to videotape their own instruction • Teachers watched video of their own teaching and responded to reflection questions posed by the project staff.
Teacher-owned	Professional development should involve teachers in selecting the content of professional development programs and, if possible, give teachers choices about learning activities.	• Teachers planned and implemented mathematical tasks on topics of their choice. These tasks addressed the state mathematics standards as well as their students' needs.
Content and theory-laden	Professional development should provide opportunities to understand the theory underlying the knowledge and skills being learned.	• Teachers worked with video and written cases to deepen their understanding of mathematical concepts as well as their students' mathematical thinking. • Teachers participated as learners in model technology-rich mathematical tasks during workshops. These tasks will also allow teachers to learn mathematics in an investigative manner, which they will be encouraged to use in their own classroom.
Collaborative	Professional development should allow teachers to collaboratively solve problems and develop the problem solving skills needed to teach effectively.	• Teachers participated in professional development with other teachers from their school. • Teachers were encouraged to co-plan and collaborate with other teachers from their building with the integration of technology-rich mathematical tasks. • The project staff worked with teachers throughout the year to provide resources, co-plan with teachers and support teachers' implementation of mathematical tasks that the teachers chose to integrate in their classroom.
Comprehensive	Professional development should be connected to a comprehensive change process focused on improving student learning.	• All of the teachers work in the same school district. • The professional development supported two statewide initiatives: improving student achievement in mathematics at the elementary grades, and preparing teachers to use more task-based activities to teach the new Georgia Performance Standards.

Student-focused

Professional development activities should prepare teachers to bridge gaps between their students' current and desired performance (Hawley & Valli, 2000; Loucks-Horsley & Matsumoto, 1999). Participants analyzed video and text-based cases of mathematics teaching and examined how the teachers in the cases enact key instructional practices. Participants also co-planned with the project staff to use instructional practices emphasized in the professional development to teach content that students typically have difficulty learning.

Teacher-owned

Teacher motivation to engage in professional development increases when they participate actively in their own learning (Loucks-Horsley et al., 2003). During the workshops, participants explored mathematics-related technologies and pedagogies, and solved mathematical tasks. They also spent time discussing how to incorporate what they were learning into their own mathematics teaching. Also during one workshop, teachers had the opportunity to use the computer to identify technologies that they could use to support their mathematics teaching.

Reflective

Professional developers have contended that teacher learning is most effective when activities are embedded in teacher's daily practice (Ball & Cohen, 1999), situated in their work (Putnam & Borko, 2000), and allow opportunities for reflection (Schon, 1983). During the year, participants co-planned three mathematics lessons in which they planned to use instructional practices that were aligned with the goals of the professional development. The first two lessons were co-planned with the project staff, while the third lesson was designed independently. The professional developers originally intended to have teachers record all three lessons and use the Video Analysis Tool (VAT; http://vat.uga.edu) to reflect on their teaching. However, the school district had blocked streaming video from entering the schools, leaving teachers with no in-school access to videos. The professional developers then modified this requirement, requiring that only the third lesson be recorded.

Content and Theory-laden

In order for teachers to enact content-specific practices, professional development must focus on specific content, learning theories, and pedagogies (Desimone et al., 2002; Garet et al., 2001). This project aimed to improve participants' comfort with mathematics-related technologies, their own mathematical knowledge for teaching, and prepare them to employ learner-centered approaches to teaching mathematics. The professional development focused on geometry, measurement, multiplication and division. During the workshops, the participants analyzed cases of mathematics instruction from the Developing Mathematical Ideas (DMI) curricula (Schifter, Bastable, & Russell, 2002), completed learner-centered mathematical tasks, and worked with mathematics-appropriate technologies.

Collaborative and Comprehensive

Research on professional development has illuminated the importance of encouraging teachers to collaborate with colleagues and form learning communities (Fishman et al. , 2003; Silver & Stein, 1996; Smith & Brown, 1997). Teachers attended workshops with colleagues from their school. They collaborated with each other to analyze the DMI cases, complete learner-centered tasks, and explore related technologies.

During the year, the teachers co-planned lessons with the professional developers. Teachers would e-mail ideas for tasks to the professional developers, who would provide feedback and offer suggestions for improving the tasks. In January, the professional developers formalized the co-planning by providing teachers with a lesson protocol that they needed to use while co-planning a lesson.

Studies on educational reform and professional development indicate that teachers are more likely to adopt new instructional approaches if the reform is part of a school, district, or statewide comprehensive effort (Fullan, 1991; Richardson, 1996). The professional development supported statewide initiatives to improve student learning in mathematics by incorporating learner-centered tasks that embodied the process skills included in the new Georgia Performance Standards (GADOE, 2005). This project also aligned with other initiatives and goals that have been implemented by the school district's mathematics coordinator.

Instruments

Video Analysis Tool (VAT)

The Video Analysis Tool (VAT; http://vat.uga.edu) provides opportunities to observe, capture, and analyze video of teacher's enacted practice (Recesso et al., in press). Figure 3.1 shows screen captures of the VAT. The VAT uses three levels of detail for examination purposes: lenses, filters, and gradients. The lenses, filters, and gradients that were used in the study, TIM-Teacher, are shown in Appendix B. These filters were identified as the six instructional practices emphasized during the professional development.

Figure 3.1: Screen capture of the Video Analysis Tool (VAT).

A lens is used to isolate activities for closer examination, such as national mathematics teaching standards (NCTM, 2000); in this study, the set of professional development practices is the lens through which teacher practices were examined. Each lens consists of filters that enable close examination of associated practices. Consistent with recommendations made by mathematics educators (e.g., Schoenfeld, 1992; Fennema et al., 1996, NCTM, 2000), in the study the filters in VAT are the 6 instructional practices emphasized during the professional development. Each filter comprises gradients, akin to rubrics, that qualitatively differentiate the extent to which professional development pedagogies are observed. Using the VAT, a rater can identify specific instances where particular practices occur, annotate and otherwise “mark up” the practice(s), refine the units of practice observed into fine-grained units using filters, and analyze the units further using defined criteria in the form of gradients. The gradients for the TIM-Teacher lens were created after examining previous research that used similar methods to examine teachers' *in situ* mathematics teaching practices (Fennema et al., 1996; Hufferd-Ackles, Fuson, & Sherin, 2004; Schifter & Fosnot, 1993). The TIM-Teacher lens was revised in September 2005, based on feedback from the researcher's committee and in October 2005 after observing a few implementations in participants' classrooms.

The VAT has been used previously across a range of pre-service and in-service settings. The researcher, and members of the researcher's dissertation committee, who are knowledgeable about effective mathematics teaching practices, refined the gradients prior to the beginning of the study. Further, the lens was modified based on observations made during the first two observations.

Interview Protocols

Baseline interview protocol. This protocol (Appendix C) was used to obtain data about participants' espoused and intended practices in mathematics. These questions were adapted from interview protocols used previously in mathematics professional development programs.

Post-observation interview protocol. This protocol (Appendix D) provided information about participants' intended and espoused practices regarding observed lessons. Using it, I asked teachers to share their intended actions during the lesson as well as successes and challenges encountered while teaching. This instrument provided information about the extent to which teachers report enacting the practices emphasized in the professional development in their teaching.

End-of-study interview protocol. The end-of-study protocol (Appendix E) was employed to document participants' reports about their espoused practices as well as their perception of how their instructional practices were influenced by the professional development. It also allowed them to report successes or barriers they experienced while putting these workshop-stressed pedagogies into daily mathematics instruction. This instrument was pilot tested with a participant from a previous professional development project.

Project staff interview. This protocol (Appendix F) was used to learn the professional developers' perspectives about the project goals and the emphasized instructional practices. The interview was conducted after the first three days of the summer workshops. This instrument was pilot tested with a graduate student who had worked on previous mathematics professional development projects.

Implementation of the Study

Table 3.3 details the activities that took place during the study. Implementation occurred both during the workshops and during participants' mathematics teaching.[2]

Activities during Workshops

Throughout the workshops, participants engaged in written and video-based cases of elementary teachers' mathematics instruction. They discussed the cases, specific instructional practices used, and how teachers attended to their students' mathematical thinking. Participants also explored mathematics-related technologies such as calculators, spreadsheets, internet-based tools, and software programs. Further, participants worked on mathematical tasks and discussed how these tasks could be adapted for use with their own students.

Activities during Participants' Mathematics Teaching

Co-planned lessons. The professional developers instructed teachers to co-plan

[2] Table 3.3 appears at the end of this section on pages 63 and 64.

their first two lessons via e-mail with the project staff. Initially, the teachers were told to e-mail ideas for tasks to the professional developer, who provided feedback and suggestions prior to implementation. The teachers were also were supposed to video record the implementation and mail it to the professional developer, who would put the video into the VAT so the teachers could review and reflect on their teaching.

Independently planned lesson. Teachers' third implementation was a lesson that they planned independently and included tasks and instructional practices that were consistent with the professional development goals. Similar to the co-planned lessons, teachers were instructed to record the lesson, mail it to the professional developer and then complete a reflection using the VAT.

Mathematics teaching activities for this study's participants. Shantel and Keisha were both purposefully selected because they reported an interest in enacting the professional development practices frequently during the school year. Therefore, it was expected that both Shantel and Keisha would do more than three implementations. Since only two of their implementations were co-planned, the participants enacted lessons that were independently planned or lessons that were taken directly from the professional development workshops (direct adoption lessons).

Directly adopted implementations had been modeled by the professional developers either during workshops or model teaching when project staff taught lessons in participants' classrooms. The directly adopted lessons were the most scaffolded of participants' implementations, since they had observed the professional developers implement the tasks and learner-centered pedagogies that were associated with the lesson.

Data Collection Activities

The data collection for this study consisted of observations of professional development workshops, examination of the participants' mathematics teaching, interviews with participants, and the assessment of classroom artifacts.

Observations of professional development workshops. I attended all of the workshops held between August, 2005 and March, 2006. This accounted for approximately the first 36 of the 48 hours of workshops. During these, I served as an onlooker (Patton, 2002) taking field notes. I focused on the project staff's discussions and the instructional practices that they explicitly discussed during the workshops. I also observed participants' activities and discussions as they engaged in the workshop's activities (e.g. cases, model lessons, lesson planning), documenting field notes and memos immediately following each workshop (Bogden & Biklen, 2003).

Observations of classroom instruction. I observed participants' mathematics classrooms on days when they intended to use instructional practices that they felt were aligned with the professional development. During each lesson I used a camera and a wireless microphone to record the implementation. I also took field notes and attended to students' actions. I typed the field notes and wrote memos for the notes in a word processor soon after the observations.

Evidence of student understanding. During implementations I videotaped and recorded field notes on the students' activities. I focused on how students represented their understanding of the mathematics content that was embedded in each task. These representations included students' arrangement of manipulatives, as well as tables, drawings, computations and answers that students generated. During observation I frequently moved the camera to record representations and roved around the classroom to look at students' work.

Table 3.3: Timeline for Research Procedures

Date	Event(s)	Research Activities	Data Collected
Aug. 2-4	Workshop	Participants attend workshops Teachers complete TIM surveys Researcher meets participants	Field notes Participant information forms
Aug. 23	Mathematics Teaching	Researcher conducts project staff interview	Audio-taped interview
Aug. 29	Make-up workshop	Keisha attends make-up workshop	
Aug. 30	Workshops	Participants attend workshop	Field notes
Sept. 15	Baseline Interview Participant Recruitment	Researcher conducts baseline interview with Shantel Researcher recruits Keisha and Beatrice	Audio-taped interviews
Sept. 29	Mathematics Teaching, Baseline Interview	Shantel completes 1st implementation Researcher conducts post-observation interview with Shantel and baseline interview with Keisha	Video of lesson Field notes Audio-taped interviews
Sept. 30	Mathematics Teaching	Shantel completes 2nd implementation Researcher conducts post-observation interview Researcher conducts baseline interview with Beatrice	Video of lesson Field notes Audio-taped interviews
Oct. 5	Mathematics Teaching	Keisha completes 1st implementation Researcher conducts post-observation interview	Video of lesson Field notes Audio-taped interviews
Oct. 12	Mathematics Teaching	Keisha completes 2nd implementation Beatrice completes 1st implementation Beatrice withdraws from the study Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Oct. 28	Mathematics Teaching	Shantel completes 3rd and 4th implementations Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Nov. 4	Workshops	Participants attend workshop	Field notes
Nov. 9	Mathematics Teaching	Shantel completes 5th and 6th implementations Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Nov. 18	Mathematics Teaching	Shantel completes 7th and 8th implementations Keisha completes 3rd implementation Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Dec. 14	Mathematics Teaching	Shantel completes 9th implementation Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Dec. 19	Mathematics Teaching	Keisha completes 4th implementation Researcher conducts post-observation	Video of lesson Field notes

		interviews	Audio-taped interviews
Jan. 4	Workshop	Keisha attends workshop Post-workshop interview	Field notes
Jan. 19	Mathematics Teaching	Shantel completes 10th and 11th implementations Keisha completes 5th implementation Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Feb. 16	Mathematics Teaching	Shantel completes 12th implementation Keisha completes 6th implementation Researcher conducts post-observation interviews	Video of lesson Field notes Audio-taped interviews
Feb. 20	Workshop	Participants attend workshop	Field notes
Feb. 21	Workshop	Keisha attends workshop	Field notes
Mar. 16	Mathematics Teaching	Keisha completes 7th implementation Researcher conducts post-observation interviews	Video of lesson Field notes
Mar. 17	Mathematics Teaching	Shantel completes 13th and 14th implementations Researcher conducts post-observation interviews	Video of lesson Field notes
Mar. 22	Collect end-of-study data	Shantel completes 15th implementations Researcher conducts end-of-study interviews	Video of lesson Field notes Audio-taped interviews

Research Questions, Procedures and Data Sources

Table 3.4 shows the alignment among the research questions, techniques, data sources, and instruments.[3] Data obtained from multiple sources (field notes and videotapes from participants' classrooms, and interview transcripts, were analyzed to examine each of the research questions. The analysis process for each question is described in this section.

Measures of Practice

This study examined participants' enacted, espoused, and intended practices in their mathematics teaching. This section describes how data for each measure of practice were collected and analyzed

[3] Table 3.4 is displayed at the end of this section on page 70.

Enacted Practices. During the study, enacted practices were observable practices that participants carried out in their teaching. Observations of participants' enactment (videos and classroom observations) were the primary data sources for determining their enacted practices. I used the TIM-Teacher lens in the VAT to code videos of participants' teaching. I watched each video after it was recorded to review the goals of the lesson and the instructional practices that they enacted. Then, I used the VAT to mark-up each video. For each video, I created sub-clips any time that I either observed one of the six instructional practices (Appendix B). These instructional practices include algorithms, tasks, student communication, mathematical representations, technology, and questions) or observed a time in which an opportunity for an instructional practice occurred. This happened for two instructional practices, *questions* and *student communication*, where there were opportunities for questions or student communication that did not occur. For each clip, there was evidence of more than one instructional practice (e.g., a teacher questions a student and provides the student with the opportunity to share their thinking while the student is generating a representation of a mathematical concept). In these instances, I marked the same clip for numerous instructional practices.

Once each video was divided into clips and marked, the codes were then entered into a Microsoft Excel spreadsheet (Appendix G). Each clip was in its own row, which included the participant, the date of the implementation, the start time and end time of each clip, each instructional practice (filter) and comments about the clip. The data were then analyzed in the spreadsheet.

For the filters *questions and student communication,* I counted all of the opportunities for these and used Microsoft Excel to calculate a percentage for each gradient within that filter (Appendix H). For the remaining filters I tallied the frequency that each gradient occurred. After tallying and determining percentages, I then examined the comments and memos to identify clips that best demonstrated the specific gradients for the filters that were prevalent during the enactments. The field notes were used to corroborate or refute the findings from the analysis of video.

Espoused and intended practices. Espoused practices included pedagogies that participants reported that they enacted in their teaching. Intended practices included pedagogies that were consistent with the professional development goals that participants planned to use in their teaching. I used data from the various interviews (i.e., baseline, post-observation, and end-of-study) as the main data sources for participants' espoused and intended practices. These interviews were audio-recorded and transcribed verbatim into Microsoft Word. Using the comment feature in Microsoft Word, I identified interview excerpts that were related to teacher's espoused and intended practices and created codes using an open-coding scheme. I copied the transcripts into a Microsoft Excel spreadsheet (Appendix I). During coding I attended to the specific instructional practices in the TIM-Teacher lens, but did not limit my coding to those practices. Appendix J lists all of the top-level codes used to analyze interview data. In the spreadsheet each interview excerpt was in its own row that contained the participant's name, the date of the interview, the interview excerpt, the line numbers of the excerpt, the initial code, and a memo about the excerpt. During analysis I created subcodes within the top-level codes for the excerpts and memoed further about the interview excerpts. Next, I used the codes and excerpts to generate data-based assertions about the participants' intended and espoused practices that related to the filters (instructional practices) in the

TIM-Teacher lens. Secondary sources (field notes from classroom observations) were used to triangulate these assertions.

Analysis of research questions

Question 1: To what extent (and how) do teachers enact the practices emphasized in a learner-centered professional development program in their mathematics teaching? Participant's enacted practices were examined based on the methods described above. Videos of teacher's enactment were the primary data source, while field notes provided data to confirm or refute the findings from the video analysis. Each implementation was analyzed separately at first. Then, implementations were grouped and analyzed according to the origin of the enacted tasks (direct adoption, co-planned, and independently planned).

Question 2: How do participants' enactments of the practices emphasized in a learner-centered professional development program compare with their espoused and intended practices? Data regarding each participant's enacted, espoused, and intended practices were coded, entered into a Microsoft Excel spreadsheet (Appendix K) and analyzed separately for each implementation. Participant's three measures of practice were then examined according to the origin of the enacted tasks (direct adoption, co-planned, and independently planned) to look for common themes and discrepancies within each lesson.

Question 3: How does evidence of student understanding reflect their teacher's enacted practices? Field notes from the implementations and video data about participants' enacted practices were used as the main data sources for this question. The data for each implementation were entered into a Microsoft Excel spreadsheet (Appendix L).

Analyzing evidence by task and task type. During the analyses, evidence was found that within each enactment, teacher-participants posed numerous tasks. A *task*, in this study, referred to any activity with a mathematical goal. During the implementations, participants enacted many tasks of the same type, referred to as a *task type*. For example, the division problem 43 divided by 6 is a task. If a student completes a worksheet with 15 tasks (2-digit number divided by a 1-digit divisor), there would be 15 tasks, but only one task type.

During the data analysis for question three, when the mathematical representations, student communication, and students' representations of mathematical work were similar, tasks enacted during the same implementation were counted as one task type. However, on multiple instances during the study Shantel posed similar tasks to her different classes, the task types were counted for each implementation since they were enacted with two different classes and the associated mathematical representations, communication, and representations of student mathematical work varied.

Validity and Reliability

Internal Validity

Internal validity is used to ensure that the findings from a research study are congruent with reality (Merriam, 2002). In order to ensure the internal validity of the study I used various strategies. These included various forms of triangulation: a) the triangulation of data sources by corroborating my findings using multiple data sources, and b) the triangulation of methodologies by collecting data using observations, videos and interviews, and c) researcher triangulation by using additional raters to code videos of classroom implementations. Further, the internal validity was increased by collecting data across multiple points in time (Merriam, 2002).

This study included data from multiple sources, such as videos of implementation, field notes from classroom observations, participant interviews, and project staff interviews. The data also included both observation-based data (i.e., videos and field notes), as well as self-reported data (i.e., interviews).

Reliability

In order to ensure reliability and accurate representation of the data I employed the previously described process of coding the data, organizing the data, generating sub-codes, making assertions and testing the assertions by reexamining the data (Coffey & Atkinson, 1996; Patton, 2002). Further, I described my biases prior to the study (see the Researcher's Subjectivity Statement in this chapter) (LeCompte & Preissle, 1993) and corroborated data from multiple sources (Coffey & Atkinson, 1996). During the presentation of findings, I used descriptive data from multiple data sources that support findings about multiple participants (Merriam, 2002).

No data in the videos or interviews suggested a fish bowl effect. According to Merriam (2002), while the presence of a researcher may have influenced participants' behaviors, multiple observations over a sustained amount of time adds to the reliability of the findings. By conducting observations for over sixteen hours in Shantel's classroom and eight hours in Keisha's classroom, I am confident that my presence did not influence participants' behaviors.

Table 3.4: Research questions, data sources and analysis

Research Questions	Instruments	Main Data Sources	Complementary Data Sources	Analysis
1. To what extent and how do teachers enact the practices emphasized in a learner-centered professional development in their mathematics teaching?	• Lens of Enacted Practices • Teacher interview protocols • Project staff interview protocols	• Field notes from observations • Videos of classroom teaching	• Interviews with participants • Interviews with project staff • Lesson plans	• Code main data sources using Lens of Enacted Practices • Identify themes in main data for each participant • Corroborate themes with interview data and lesson plans • Analyze data across participants
2. How do participants' enactments of the practices stressed in a learner-centered professional development program compare with their espoused and intended practices?	• Lens of Enacted Practices • Teacher interview protocols • Project staff interview protocols	• Field notes from observations • Videos of classroom teaching • Interviews with participants • Interviews with project staff	• Lesson Plans	• Code field notes and video data using Lens of Enacted Practices • Code interview data using Lens of Enacted Practices as a framework • Identify themes in each data source • Identify themes for each participant • Analyze data across participants
3. How does evidence of student learning reflect teachers' enacted practices?	• Lens of Enacted Practices • Teacher interview protocols • Project staff interview protocols	• Field notes from observations • Videos of classroom teaching • Student work samples	• Interviews with participants • Interviews with project staff	• Code main data sources using Lens of Enacted Practices • Analyze student work samples and enacted practices for each participant • Identify themes for each participant • Analyze data across participants

Interactions between the Researcher and the Participants

During the research study I developed a relationship that was both collegial and professional with the participants. While I never formally led a professional development workshop prior to or during the time that I was collecting data, participants may have associated me with the TIM project. The participants knew that I worked in the same office with the professional developers and shared rides with them to the workshops throughout the year. During the year when the VAT was not working in the school, I helped the participants as well as other teachers in their school try to watch their videos. I was concerned throughout the study about participants viewing me as a participant observer rather than a non-participant observer.

As a result of this concern, I explicitly took precaution in numerous ways. First, I observed their teaching only when participants reported that they intended to use instructional practices that they felt were aligned with the professional development goals. Thus, every observation occurred when participants thought that they were enacting instructional practices that were covered in the workshops. These purposeful observations made participants' perception of my role germane since participants' perception of the emphasized instructional practices came from the workshops and the professional development staff leading the workshops.

During classroom observations I was also careful about maintaining my role as an onlooker. After the participants finished teaching they asked for feedback about their teaching every time. In each instance, we conducted the post-observation interview the same day of the implementation, so I could capture the participants' voice and their report about the lesson soon after the lesson was completed. When the participants asked me for feedback I would respond with general remarks, such as “I thought it was fine” or “I need to go back and watch the video.” While not providing feedback was difficult and ethically perplexing, this approach ensured that I was minimizing my intervention on my participants’ classroom practices.

Researcher’s Subjectivity Statement

My previous experiences as an elementary school teacher, as a participant in professional development programs, and as a professional developer have influenced the way that I view effective professional development programs and the process of supporting teacher learning. While my study’s methodology attempts to limit the bias of my subjectivity, this statement provides background on my professional experiences that may influence my work as a researcher.

I was an elementary school teacher for three years and a participant of a number of professional development initiatives. While I enjoyed the professional development programs, I was aware that I was not benefiting much from them. For the most part, these programs spent hours covering content and activities that had no or little relevance to my teaching practice. That was quite frustrating.

Luckily, my experiences with professional development programs shifted during my second year of teaching. My principal selected me to participate in a Preparing Tomorrow’s Teachers to Teach with Technology (PT3) grant that prepared teachers to integrate technology into our classroom. The PT3 project was very flexible; the professional developer introduced a piece of technology and allowed us to choose whether we spent the workshops becoming familiar with technology, discussing how the technology could be effectively integrated into our classes, or planning lessons that used the technology. I left the workshops excited about my experience. Also, I had a tangible way that I could incorporate my new knowledge into my classroom. This experience opened my eyes to the potentially powerful effect that professional development can have on teachers.

Based on prior research that I have read and studies that I have conducted, teachers are more likely to enjoy professional development programs that allow them to take some ownership of their learning. While completely individualized programs are difficult to design and implement, teachers' opportunities for learning should be individualized enough so that teachers feel that they are learning things that are relevant to their teaching. I believe that teachers need to be able to leave professional development with an idea about what how their experience will influence their teaching and their students' learning.

Based on my experiences, I began the research expecting that my participants would benefit from and enjoy their participation in the TIM project. I expected that the participants would be excited to apply some of their new knowledge into their classroom, especially tasks that involve technology. However, I expected that participants might have difficulty with the barriers that teachers typically face, e.g., access to technology that works, initial problems when implementing learner-centered tasks for the first time, using manipulatives and technology to support student learning, and learning how to design learner-centered tasks. I also am aware that teachers require a lot of time, in professional development workshops learning about new practices and resources, as well as in their classrooms trying new approaches and making sense of their new knowledge and how it can enhance their students' learning experiences.

Due to these factors, I was cautiously optimistic about how teachers' enactments will align with the professional development practices. I believed that teachers would benefit from the TIM program. This was especially the case, since I worked with teachers who reported both interest in the professional development and willingness to enact TIM-related instructional practices throughout the school year. However, since both participants had just begun the professional development project, I was unsure on whether the teacher-participants would enact any TIM-related practices and how their enactments would reflect their learning during the short time of the study.

Chapter IV

FINDINGS

Overview of Participants

Shantel. Shantel, an African-American female, had been teaching the 5th grade for 13 years. Shantel taught three departmentalized mathematics classes daily: one with students in the Early Intervention Program (EIP) and two with students at grade level (AGL-1 and AGL-2). During her baseline interview, she indicated her intention to use professional development-related practices in order to change her teaching in what she referred to as a “good way” to help her students learn. Shantel reported that she taught the same content to each of her classes but tended to teach the EIP students more didactically than her AGL classes. She described her desire to use problem solving with her EIP class:

> I see that there is a difference [between classes], but I think that it’s possible for EIP students to [solve word problems]. I want to let them see you can have so much more success if you will just try and do this and that’s my goal for them.

Shantel’s baseline interview provided evidence of differences in teaching practices between her EIP and grade-level classes; specifically, she reported that she used more teacher-directed and reinforcement tasks in her EIP class. Therefore, during each observation I attempted to record both her EIP and one of her AGL classes (AGL-1 and AGL-2). During the first 3 months of the study, Shantel frequently reported her intentions to implement tasks that embodied the instructional practices emphasized in the professional development; Nine of Shantel’s 15 enactments occurred between late

September and December. A majority of these enactments were not related to the professional development's mathematics content; however, Shantel espoused their alignment with the target instructional practices. Beginning in January, Shantel voiced fewer intentions to enact professional development-related practices. During post-observation interviews, she reported feeling pressured to address required content prior to the district's assessments and the statewide Criterion-Referenced Competency Test (CRCT).

Keisha. Keisha, an African-American teacher, has completed six years of teaching, including four years as a 4^{th} grade teacher. Keisha finished her specialist degree in Educational Leadership in August, 2005, and described herself during her baseline interview as "a lifelong learner." In her first year, Keisha did not teach mathematics, so this year was Keisha's third year of teaching 4^{th} grade mathematics. Keisha frequently characterized herself as a "different" teacher because she used manipulatives, games, songs, videos and other instructional strategies to teach mathematics to her students. During her baseline interview, she credited her friendship with Shantel for igniting her love of teaching mathematics:

> Shantel showed me how [teaching mathematics] can be fun and it doesn't have to be book, book, book, all the time. If you use hands-on with the kids or if the kids are playing games and just to see their faces when you are doing something that's not the traditional book method you see their faces light up. When you see the kids enjoying it, of course you enjoy it.

Keisha was selected because she was interested in attempting to implement the professional development's instructional practices into her classroom. However, I expected that Keisha would likely experience barriers during implementation since she missed the first 18 hours of the professional development due to a family emergency.

Although she subsequently made up the workshop hours during the school year, I was not able to record classroom enactments until she had completed the first 12 hours of the professional development program. Five of her seven of enactments occurred after she had completed 24 hours of professional development workshops.

Keisha enacted seven lessons, six of which were related to the professional development's mathematics content; three included tasks that she had either directly adopted from the professional development or had co-planned with the professional developer. During post-observation interviews, Keisha frequently referenced her enactments between observations that were aligned with the TIM-instructional practices. However, since she did not notify me prior to those days, evidence related to her enactments was not captured.

Framework for Analysis: Enactment in Relation to Task Origin

During classroom observations and initial stages of data analysis, differences in teacher practice emerged as a function of the task origin. Table 4.1 summarizes the five task origins enacted in this study. Tasks adopted directly from professional development activities or co-planned with the professional developer typically emphasized learner-centered activity and characteristically provided opportunities for students to use manipulatives and investigate mathematical concepts embedded in the tasks. While co-planned and independently planned tasks typically involved student use of manipulatives, they stressed teacher-centered activities and did not necessarily reflect the professional development's mathematics content.

Table 4.1: Origins of Tasks

Origin of Tasks	Intended practices	Participant	Content
Direct Adoption	A teacher intended to enact tasks that they either participated in during professional development or observed the professional developer enact in their classroom during model teaching	Keisha	Geometry
		Shantel	Division (EIP)
			Division (AGL)
Co-planned lesson related to professional development content	A teacher intended to enact tasks related to the professional development's mathematics content. The teacher planned the tasks independently, received feedback from the professional developer and then enacted the tasks.	Keisha	Multiplication
			Area and Perimeter
Co-planned lesson not related to professional development content	A teacher intended to enact tasks not related to the professional development's mathematics content. The teacher planned the tasks independently, received feedback from the professional developer and then enacted the tasks.	Shantel	Representations of decimals (EIP)
			Representations of decimals (AGL)
			Adding and subtracting decimals (EIP)
Independently planned lesson related to professional development content	A teacher intended to enact tasks that they planned independently and related to the professional development's mathematics content	Keisha	Array models of multiplication
			Multiplication and division
		Shantel	Properties of triangles (EIP)
			Linear measurement (EIP)
			Linear measurement (AGL)
Independently planned lesson not related to professional development content	A teacher intended to enact tasks that they planned independently and are not related to the professional development's mathematics content.	Keisha	Bar Graphs
		Shantel	Least Common Multiples (Grade-level)
			Least Common Multiples (EIP)
			Prime Numbers (EIP)
			Prime Numbers (AGL)
			Adding Decimals (EIP)
			Adding Decimals (AGL)

Figure 4.1 shows a timeline of implementation based on the origin of the tasks. The professional development requirements included two enactments that were co-planned with the professional developer (CC or CNC) and one enactment that was independently planned (IC or INC). Both participants also directly adopted tasks from professional development activities (DA). Shantel’s first enactment counted as one of her co-planning lessons, because the professional developer co-planned the lesson and implemented it in her classroom before Shantel taught the lesson to her two other classes.

		Sept	**Oct**			**Nov**		**Dec**		**Jan**	**Feb**	**Mar**	
Teacher	**Class**	**29-30**	**14**	**21**	**28**	**9**	**18**	**14**	**19**	**19**	**16**	**16-17**	**22**
	EIP	DA			INC	INC	INC	IC		IC	INC	CNC	CNC
	AGL-1				INC	INC				IC		CNC	
Shantel	**AGL-2**	DA					INC						
Keisha			IC	IC			CC		INC	DA	IC		CC

Key

DA: Direct Adoption

CC: Co-planned and based on the professional development's mathematics content

CNC: Co-planned and not based on the professional development's mathematics content

IC: Independently planned and based on the professional development's mathematics content

INC: Independently planned and not based on the professional development's mathematics content

Figure 4.1: Timeline of enactment based on origin of tasks.

Building on the analysis done using VAT, I entered the time, gradient, and comments for each filter into an Excel spreadsheet (Appendix G). I then calculated the frequency and percentages for every gradient of the six instructional practices for the implementations. In the spreadsheet, I compiled all of the enactments for each origin of task (e.g., direct adoption, co-planning a lesson based on professional development content) and calculated the frequency and percentages for every gradient of the six instructional practices (Appendix H).

This chapter presents data and evidence for the study's three research questions. The findings are organized according to the five task origins. Appendix M provides an overview of participants' implementations.

Question One:

To what extent (and how) do teachers enact the practices emphasized in a learner-centered professional development during their mathematics teaching?

Direct Adoption

Both teachers adopted a lesson directly from the professional development and implemented the tasks in their classrooms. Keisha adopted a geometry task that the professional developer planned and implemented during a workshop, while she participated as a learner. Shantel adopted division tasks that she co-planned with the professional developer and observed him implement with her AGL-1 class. Shantel then enacted the lesson with her AGL-2 that afternoon and with her EIP class the next day. Five of the six TIM-Teacher instructional practices (Appendix B) were evident during enactment; student communication was limited to students responding to teacher's questions.

Mathematical tasks. Consistent with the TIM-instructional practices, each enacted task incorporated manipulatives to support task completion. These tasks allowed each student to use concrete materials to represent the mathematical concepts that they were working with. Each student was provided a set of materials, which they used during the task. Despite access to materials, students in both of Shantel's classes experienced difficulty connecting the manipulatives to the task context. They completed the tasks successfully with guidance, but were unable to explain what the manipulatives represented. For example, students worked on the task, “If 54 treats were going to be split among four students, how many treats will each student get?” Students divided 54 base-10 blocks into four piles, so that there 13 blocks in each pile and 2 blocks without a pile (Figure 4.2). When Shantel asked the class how their answer connected to the task’s context, students were unable to communicate that each student would receive 13 treats. During her first enactment, Shantel responded to her AGL-2 class’ struggles by posing a task, 19 divided by 3, that was not contextualized. Students successfully solved the task using the base-10 blocks, but the class ended before Shantel posed a contextualized task; during her post-observation interview, she shared her intent to pose a contextualized task if time permitted.

Figure 4.2: Picture of a student showing 54 divided by 3 on the overhead projector.

Keisha’s students also experienced problems using manipulatives during the lesson. Keisha mistakenly provided each student with two sets of tangrams to complete a task that required only one set. Students spent the first 25 minutes of the 40-minute lesson attempting to complete the tasks by trying to make puzzles using two sets of tangrams rather than one. Keisha noticed the problem and announced to the class that they should only use seven tangram pieces (Figure 4.3). However, since she did not specify that they needed to use the seven pieces from the same set, students continued to use incorrect number and types of tangrams throughout the lesson. Despite seeing the professional developers model how to enactment these tasks, both participants experienced difficulty during their implementations.

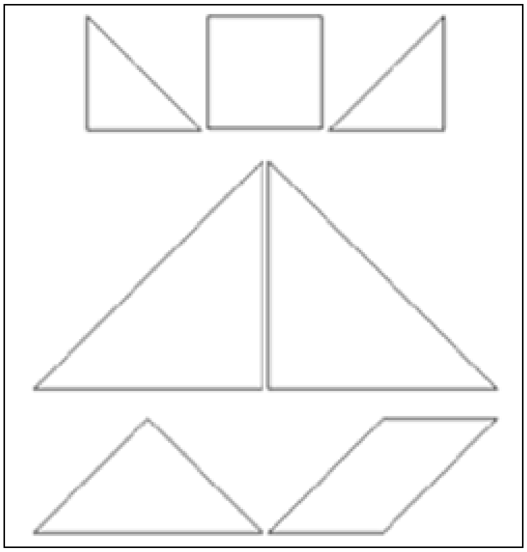

Figure 4.3: A set of tangram pieces.

Algorithms. Algorithm use was evident only during Shantel’s lessons. Her implementation shifted from focusing on the traditional algorithm during the first enactment to explicitly discussing with students how the enacted task related to the traditional algorithm during the second enactment. During the model teaching in Shantel’s AGL-1 class, the professional developer facilitated a discussion where he explicitly related the base-10 blocks to the traditional division algorithm and introduced an alternative algorithm. Shantel’s second enactment more closely aligned with the professional developer’s implementation than her first enactment. During Shantel’s first enactment she told students, “I want you to solve this using both division on paper and the base-10 blocks.” She allowed students to choose which approach they would use initially; every student used the traditional algorithm prior to using the base-10 blocks. While students successfully used the traditional algorithm, they were unable to set up the base-10 blocks without guidance from Shantel.

Shantel modified her approach during her second enactment, where she required students to use the base-10 blocks prior to the traditional division algorithm. During the implementation, she discussed the relationship between the base-10 blocks and the division algorithm, concluded the lesson by introducing the alternative algorithm, and had the students complete three tasks using the alternative approach.

Questions. Both participants actively examined students' work and posed questions throughout the enactments. Further, each participant posed questions related to student's mathematical thinking. However, a majority of these questions focused on students' work with manipulatives and the procedures used to complete the tasks. While both teachers questioned students, a majority of these questions elicited direct answers or mathematical definitions (level-one questions).

While both teachers focused on basic questioning strategies, Shantel's questioning improved between enactments. During her second enactment, in a whole class discussion, Shantel's posed two questions that prompted students to share their mathematical thinking (level-two questions). Keisha frequently asked students which tangram puzzle they were working on. At times, she posed a follow-up question such as, "Which shapes will you need to use?" In one instance, she stopped to question a student who was moving two different size triangles and asked:

> Keisha: "What's the difference between this triangle and that triangle?"
> Student: "Different size"
> Keisha: "Would they be called congruent?"
> Student: "No"

Keisha: "Why not?"
Student: "They have to be the same size same shape"
Keisha walks away.

Once the student repeated the definition copied in their notebooks the day before ("same size same shape"), Keisha moved on to a different student. When this task was enacted during a professional development workshop, the professional developer posed level-one questions about transformations (e.g., translations, reflections and rotations) and followed-up with level-two questions about the approaches that participants were using and their mathematical thinking in regards to their approach.

While Keisha posed high-level questions about mathematical thinking, most of her questions focused on definitions and terminology. In the example below, Keisha asks a student how he created a rectangle out of four triangles:

Amos is working on a tangram puzzle. On his desk he has combined four right triangles to form a rectangle.
Keisha: "I actually see a rectangle going on. What did you have to do to make the rectangle?"
Amos: "Two squares."
Keisha: "Two squares. But those squares I see here are small squares and you made big squares so what did you actually do?"
Amos: "I put two big triangles together."
Keisha: "Oh you put two triangles together and those two triangles made what?"
Amos: "A square."
Keisha: "A square. Okay. So to make that rectangle what did you actually do? What did you put together?"
Amos: "Four [Amos pauses] four triangles."
Keisha: "Four triangles."
[Keisha nods and walks away]

Upon noticing Amos' rectangle comprised four right triangles, Keisha asked Amos to explain how he created the rectangle. Consistent with the instructional practices of the professional development, Keisha continued to question Amos until he explained his approach to completing the task.

Technology and mathematical representations. Shantel's use of the overhead projector was the only technology used during adoption enactments. Differences were detected between participants in their use of technology to support students' mathematical representations. Shantel used the overhead projector to model using base-10 blocks to represent the task as well as trading one rod (that has a value of 10) for ten cubes (that each has a value of one). During Shantel's first enactment with her AGL-2 class, students immediately began the task without attending to her modeling. Students successfully solved the task using the traditional division algorithm but struggled when attempting to trade base-10 blocks in order to complete the task "If 52 fifth graders were going camping and sleeping in tents that held three people how many tents would we need?" While students were able to set up the task, they needed Shantel's assistance to split the blocks among the three piles. During the interview following Shantel's first enactment, she reported that her EIP students needed modeling prior to starting the task. Thus, during her second enactment with her EIP class, she required students to mimic her representation and complete the task while she modeled the processes on the overhead projector; students were more successful using the base-10 blocks to represent and complete the task.

Keisha did not model strategies for her students during her adopted lesson. Rather, she distributed tangrams and immediately instructed students to begin working on their puzzles. Keisha's students had two sets of tangrams on their desk, even though only one set was required. The students merged the two sets and attempted to make their tangram puzzles from two tangram sets as opposed to only one set.

Summary. Tasks that were directly adopted from professional development activities were designed to be learner-centered and consistent with the professional development instructional practices. However, both participants struggled with their enactments of these tasks. Shantel decontextualized tasks that were intended to provide students with real-world division problems. Keisha, meanwhile, provided too many manipulatives and focused on the surface features of the task (making tangram puzzles) as opposed to the mathematics embedded within the task.

Co-planned Lessons based on Professional Development Mathematics Content

Participants' lessons that were co-planned with the professional developer and related to the professional development's mathematics content varied greatly in terms of the enacted tasks and other related instructional practices. Keisha designed two lessons that involved co-planning and implementing a lesson related to the professional development's mathematics content. Shantel did not implement any lessons of this type. For both lessons, Keisha e-mailed tasks to a professional developer, who suggested modifications and approaches for employing the tasks in her classroom. All six of the emphasized instructional practices were evident during the enactments.

Tasks, Algorithms and Mathematical Representations. Compared to her first co-planned enactment, Keisha's second implementation was more aligned with the professional development instructional practices, in terms of the enacted tasks, and the use of algorithms and mathematical representations. Keisha's first lesson contained 5 low-level tasks that focused on multiplication skills: three tasks in which students did not use manipulatives or technology to support task completion (level-one tasks), and two tasks in which students used technology and manipulatives and a procedure given by the teacher to complete the task (level-two tasks). Her second enactment, however, demonstrated more high-level tasks than her first enactment, and included four tasks that allowed students to use materials (plastic square tiles, see Figure 4.4) and develop their own approach to determine the area and perimeter of rectangles (level-three tasks).

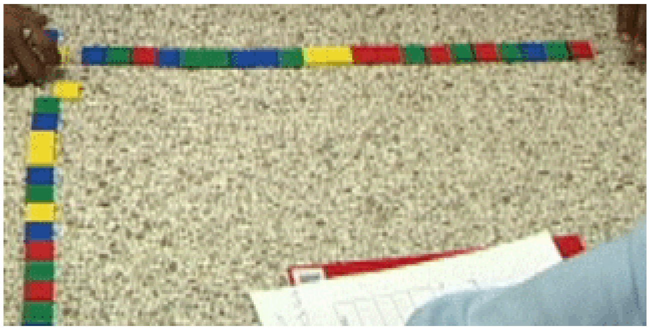

Figure 4.4: Students determine the area and perimeter of a hallway tile.

Keisha's first enactment focused on students' multiplication skills and traditional multiplication algorithms, where she explicitly reminded students about the steps in the algorithm. During her second enactment, Keisha's students selected their individual approaches to calculating area and perimeter of the rectangles. During the second enactment, she made frequent references to algorithms (e.g., area equals length times width). However, throughout the lesson Keisha also asked students to justify their algorithmic approach.

Student communication. While both lessons included student communication, discourse during the first implementation focused on answer sharing but included student discussion about how to complete the tasks during the second implementation. During the first enactment, students shared answers for three of the five tasks; during the second enactment, students discussed how to best complete the tasks. While the second lesson included opportunities for communication, some students disagreed with their groups' approaches and appeared visibly frustrated. In the following, a group of students was determining how they might measure the area of a desk:

> Keisha: “Are you doing the area of the desk first or the perimeter of the desk?”
> Rose: “Area.”
> Trevon: [*interrupting Rose*] “It’s 25 across so instead of filling it all up.”
> Keisha: “Listen you’re telling me what to do but your group members are not listening.”
> Trevon: “It’s 25 across and 20 going down we can do 20 times 25.”
> Keisha: “Alright what do ya’ll think about that?”
> Trevon: “Yeah.”
> Keisha: *[turns to S2]* “I know you’re going to say yes it’s your idea. What do ya’ll think? *[turns to the other three students in the group]* Remember if ya’ll disagree you need to talk about it.”
> *The other three students remain silent.*
> Trevon: “Cause look it’s if we get this and we fill in all of that it’s going to be 25 in each one of them and 20 going down it’s going so if we fill it all in it’s going to be 25 going across so that’s why I’m saying 25 for all of it right there [moves finger across] and 20 going down.”
> *Keisha calls other students by name and asks them what they think.*
> Rose: “I agree.”
> *The other two students nod*
> Keisha: “So what are you going to do?”
> Trevon: “25 times 20.”
> *Keisha walks away.*

While Keisha attempted to facilitate group discussion and student-to-student discourse, Trevon interrupted and the conversation shifted to a teacher-student interaction while the other students observed rather than participated in the conversation.

Technology. Students used technology (in three of five tasks) to either generate tasks or receive feedback to answers that students solved using paper and pencil during the first enactment. For example, students used the Brainchild (Figure 4.5), a handheld computer system that provided multiplication tasks, multiple-choice items and feedback based on student answers. During another task, Keisha’s students played the factor game (Figure 4.6, http://illuminations.nctm.org/ActivityDetail.aspx?ID=12), an Internet-based game designed to support students in developing conceptual understanding of factors (level-four technology use). While the game featured a high-level use of technology, its purpose was not explicit and while the directions appeared at the bottom of the screen, students did not read them and were largely off-task except when Keisha attended to those working on the task.

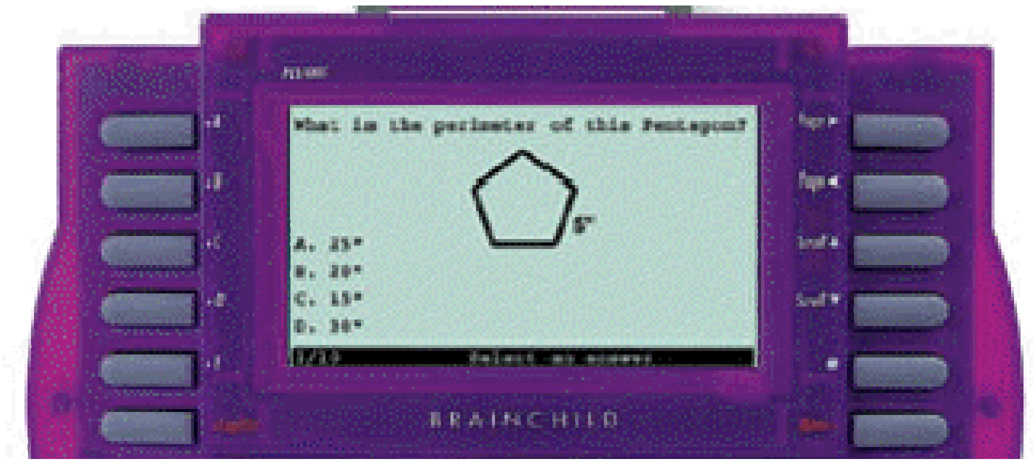

Figure 4.5: The Brainchild computer system.

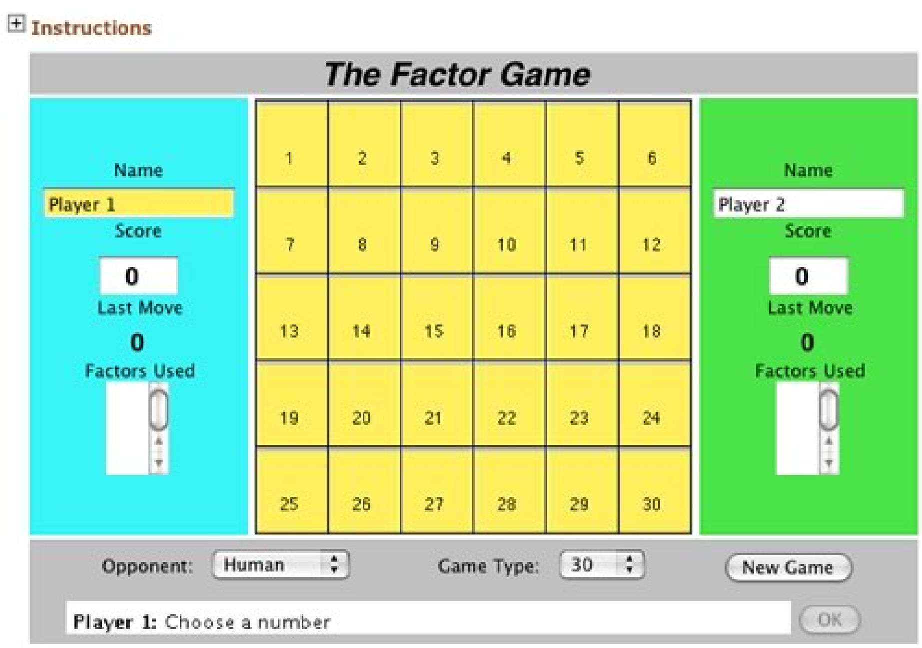

Figure 4.6: Screen capture of the Factor Game.

Questions. Questioning during Keisha's second enactment improved substantially from her first enactment. Whereas during her initial implementation Keisha did not question students' mathematical thinking and required mathematical answers or the steps of the traditional multiplication algorithm (15 of 38 opportunities, 39.47%), her second enactment (11 questions of 31 opportunities, 35.48%) elicited mathematical thinking. These questions focused on how students were completing the tasks and justifying their approach such as, "what are you doing?" and "why did you choose that approach?"

While questions during the second enactment probed students' mathematical thinking, Keisha's inquiries revealed her misconceptions about area and perimeter and did not facilitate student learning. On two occasions, Keisha questioned groups who were measuring the perimeter by placing tiles inside the sides of a desk rather than on the outside of a desk. Keisha eventually told both groups to move to a desk that was surrounded by desks of equal height (Figure 4.7). She told one group, "Remember the perimeter is the distance around so you want to put tiles around the desk not on top of it. If we put tiles on the desk that means we're finding the area." The TIM workshop had included a similar task approximately one month earlier in which students successfully measured perimeter by placing tiles inside the sides of the rectangle. During the post-observation interview, Keisha reported:

> When we're talking about the perimeter of something we're talking about how that's the distance around so if they were simply just placing tiles on top of the desk they wouldn't be finding the perimeter of [the desk] that's finding the area.

This apparent misconception influenced the nature of Keisha's questions during her teaching enactment.

Figure 4.7: Students finding the area and perimeter of a desk.

Summary. Keisha's first enactment included skill-based tasks that focused on traditional algorithm use, while her second enactment consisted of student-directed tasks supported by the use of manipulatives. While the first lesson included technology, three of the four technology-rich task types were not consistent with the professional development pedagogies. These tasks focused on the traditional multiplication algorithm. Keisha's second enactment, however, was more consistent with the professional development instructional practices; students collaborated with one another and responded to Keisha who monitored by asking questions about students' mathematical thinking.

Co-planned Lessons not based on Professional Development Mathematics Content

During the last week of the study, Shantel enacted an equivalent decimals lesson that she had previously co-planned with the professional developer; Keisha did not implement these types of co-planned lessons. Shantel taught the lesson three times. During the first day she enacted the lesson in both her EIP and her AGL-1 class. However, since her EIP class did not finish the lesson, she completed the lesson a week later. Instances of student communication during these enactments occurred only when students responded to teacher's questions.

Tasks and mathematical representations. During her three lesson enactments for this category, Shantel's EIP and AGL-1 classes completed different types of tasks (Appendix M). Shantel reported that her AGL-1 class understood equivalent decimals already and did not need to work with the base-10 blocks; she intended to start with base-10 blocks with her EIP students and then transition to paper-based tasks. Although Shantel read decimals orally to both classes, she asked classes to represent the decimals in different ways. EIP students represented decimals with base-10 blocks and in numerical form on a place value chart, while students in her AGL-1 class wrote the decimals in numerical form on a miniature whiteboard, so Shantel could provide feedback. Shantel's AGL-1 class finished the written tasks in 25 minutes before going to the computer lab; her EIP class spent 55 minutes working with classroom-based tasks.

EIP students were initially unable to complete the tasks; they repeatedly put the incorrect base-10 blocks on their place value mat. After the second task, Shantel began holding up correct examples of students' work, which led to more successful task completion. By the end of the lesson, students had met Shantel's goal; they were able to write a decimal and an equivalent decimal in numerical form without using base-10 blocks.

Technology. Variability was also evident between the technology used by Shantel's EIP and AGL-1 classes. At Shantel's request for technology integration ideas, the professional developer recommended a website (Figure 4.8, http://nlvm.usu.edu/en/nav/frames_asid_ 264_g_2_t_1.html) where students manipulate base-10 blocks as associated calculations are shown on the computer. Shantel first used the website with her AGL-1 class, but did not let her entire class work on that website.

She instructed the stronger students to work on the website, while the remaining students completed a series of skills-based tasks (Figure 4.9, http://www.aaaknow.com/dec312x3.htm). The students who completed the skills-based tasks finished quickly and were assigned to complete additional skills-based tasks on the computer. One week later, Shantel's entire EIP class worked on the recommended website (Figure 4.8). Some students successfully used the virtual base-10 blocks to support task completion. Others moved the virtual base-10 blocks on the screen but were unable to complete the tasks unless Shantel provided explicit details about how to carry and regroup the virtual base-10 blocks. Shantel provided explicit details to six students during the implementation: four were already completing the tasks successfully, while two of the students were unable to move the base-10 blocks into the correct columns.

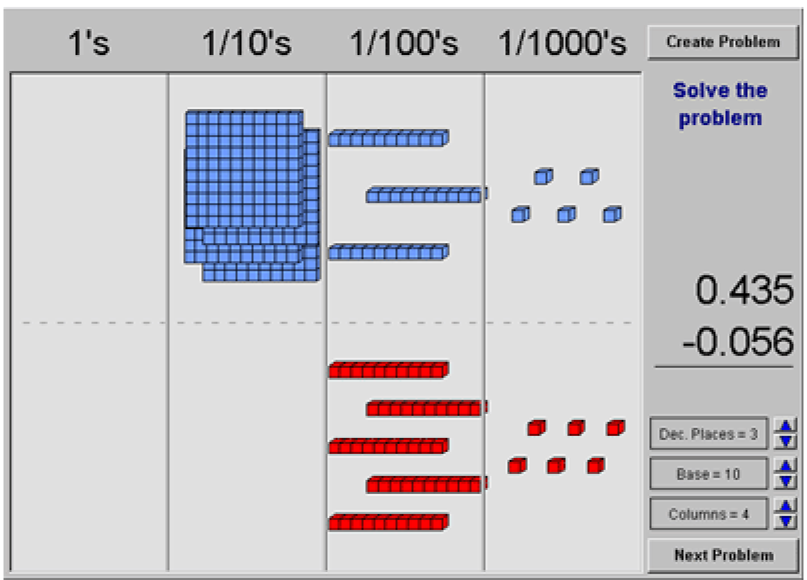

Figure 4.8: Subtraction of decimals tasks.

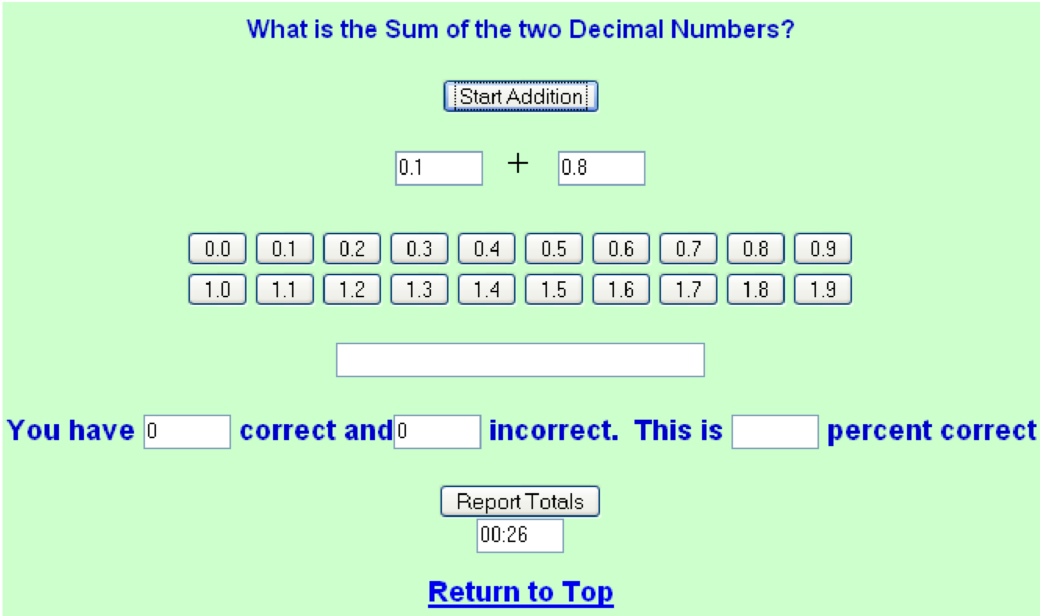

Figure 4.9: AAA Math Addition of decimals tasks.

Questions. Across the three enactments, Shantel increased the frequency of her level-two questioning. In contrast to her second enactment, when her AGL-1 class worked on the computers as she circulated in the classroom but did not pose questions, her questions during her third enactment became increasingly focused on the mathematics. Questions that elicited students' mathematical thinking (level-two) increased from 4.88% (2 of 41) during the first enactment to 23.81% (5 of 21) in the second enactment, to 40% (8 of 20) during the third enactment. A majority of questions involved simply asking, "Why are you doing that?" Shantel asked students multiple questions during her third enactment; She asked students questions about the answer that they got and then posed follow-up questions that attempted to elicit explanations about whether students needed to carry or regroup while completing the addition and subtraction tasks.

Algorithms. Evidence involving use of algorithms only occurred during the third enactment, when Shantel was in the computer lab with her EIP class. Shantel questioned one student about whether she needed to carry 10 tenths pieces to the ones column during an addition problem. As the student started on the left and began subtracting in the ones column before the tenths and the hundredths columns, Shantel asked:

> Why did you go and start in the ones? When you subtract you did this [*points to ones*] then you did this [*points to tenths*] then you do this [*points to hundredths*]. Is that how you would do it on paper? How would you do it on paper? [*Student continues to work without explaining. Shantel walks away.*]

Through her questioning, Shantel attempted to help the student relate this task to the traditional subtraction algorithm that she taught her students to use with paper-based tasks.

Summary. Shantel's co-planned lesson included different task types. EIP students used base-10 blocks to represent a decimal that Shantel read orally, while AGL students wrote the decimal in numerical form without manipulatives. Shantel posed more questions about her students' mathematical thinking to her AGL students, and focused more on answers and procedures when her EIP students struggled. Across her two implementations, Shantel's use of technology shifted. Students in her first class (AGL-1) that were proficient completed concept-focused tasks, while her struggling students worked on skills-focused tasks. However, during the enactments with her EIP students, Shantel allowed all students to work on technology-rich concept-focused tasks.

Independently Planned Lessons Based on Professional Development Mathematics Content

Keisha and Shantel both independently planned and implemented lessons related to the professional development's mathematics content. Keisha enacted three lessons during which students worked with the partial product multiplication algorithm, constructed array models of multiplication, and solved multiplication and division puzzles. Shantel also enacted two lessons. Her EIP class examined types of triangles, and both her EIP and AGL-1 class estimated the length of classroom objects. Appendix M provides an overview of participants' implementations. Based on the analysis of video and field notes, all professional development instructional practices were evident during their implementations.

Tasks and mathematical representations. Consistent with the TIM instructional practices, five of the six enactments in this category included hands-on tasks in which students drew pictures and used rulers, geoboards, and calculators. Two of Keisha's three lessons and Shantel's lesson on linear measurement were similar to the enactment demonstrated in the professional development workshops; students used manipulatives to support task completion and generate mathematical representations. During Shantel's geometry lesson, students used manipulatives but recorded neither their work nor their answer on paper; during Keisha's lesson on the partial-product multiplication algorithm, no manipulatives were used.

While a majority of the tasks included the use of manipulatives or technology (level-two and level-three tasks), classroom implementations deviated from the lessons' mathematical goals. During her lesson on array models of multiplication, 30 minutes passed before students began making array models—Keisha's espoused goal for the lesson. Prior to making arrays, students listened while Keisha read a story about multiplication, watched a 10-minute video about array models of multiplication, and wrote definitions related to the task. After they copied the definitions, 15 minutes remained for students to initiate and complete the process of making arrays. Keisha's students completed the arrays; students had one-digit by one-digit multiplication problems rather than two-digit by one-digit problems which were more appropriate for their grade. Students completed the arrays quickly before starting to work multiplication problems from their textbook.

During Shantel's lesson on triangles, each of her EIP students used rubber bands to make identical triangles on their geoboards (Figure 4.10); however, their constructions reflected different side lengths and triangle identifications (e.g. equilateral, isosceles, or scalene). The students used different-sized geoboards, measured in different units (centimeters and inches), and did not properly line up their rulers with the vertices of the triangle. Shantel spent 12 minutes asking individual students about the side lengths while they worked at their desks. She did not address errors in the students' measurements.

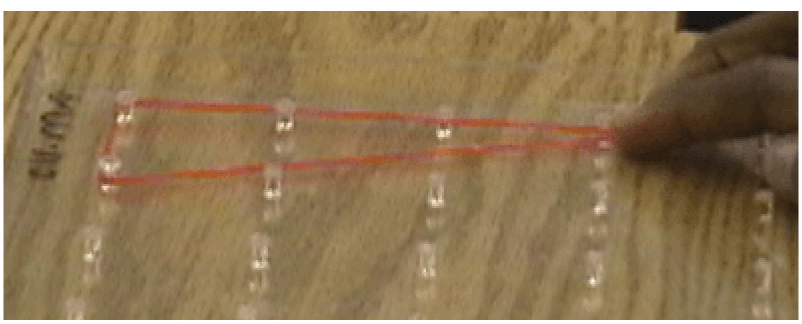

Figure 4.10: One of Shantel's students uses a geoboard to construct a triangle.

Questions. Both participants posed questions related to students' mathematical thinking (level-two). During Shantel's lesson on triangles with her EIP class, she posed 9 questions (out of 26 opportunities, 34.62%) about students' mathematical thinking. Consistent with the professional development instructional practices, Shantel asked numerous follow-up questions; however, the questions did not elicit information about students' mathematical thinking. After a student incorrectly characterized a triangle as equilateral, the following exchange occurred:

> Shantel: "what are the lengths, Mya?"
> Mya: "10, 11 and 9"
> Shantel: "O.K. so what kind of triangle did you say it was?"
> *Mya whispers*
> Shantel: "what?"
> Mya: "equilateral"
> Shantel: "10 11 and 9 and that's equilateral? What word do you hear in equilateral?"
> Mya: "Equal"
> Shantel: "O.K. so are all those sides equal?"
> *Mya shakes head*
> Shantel: "So can this possibly be an equilateral triangle?"
> Mya: "No."

While Shantel posed follow-up questions, they did not prompt Mya to explain her thinking; rather, Shantel's questions led Mya to conclude that the triangle could not be equilateral. Shantel walked away and did not question Mya about whether the triangle was scalene or isosceles.

With one exception, Keisha's independently planned tasks were teacher-centered. During her last independently planned lesson, students chose either multiplication or division to complete the blanks in a number puzzle (e.g., 24 __ 8 __ 2 __ 5 = 30). The implementation of multiplication and division puzzles included 6 level-two questions (22.22%) compared to only 2 questions in her first enactment.

Despite instances of high-level teacher questioning, participants' questions in every enactment primarily focused on providing answers or mathematical definitions (level-one). Across independently planned enactments based on the professional development content, the percentage of level-one questions ranged from 57.69% (15 of 26 opportunities to question) in Shantel's triangle lesson with her EIP class to 85.19% (23 of 27) in Keisha's lesson on array models of multiplication.

Technology. Both teachers used an overhead projector to model processes to support task completion. The overhead projector was used to launch tasks in all three of Keisha's enactments and Shantel's triangle lesson. In each case, teachers modeled procedures on the projector while students mimicked the procedures at their seat. Most students attended to the modeling and started the tasks. For example, Shantel showed a geoboard on an overhead projector while students created a triangle identical to the one she displayed.

Students only used a calculator during Keisha's implementation of the multiplication and division puzzles to help them complete the tasks. The computations ranged in difficulty from a one-digit by one-digit multiplication problem to a two-digit by one-digit division problem. At the beginning of class, Keisha showed a calculator on the overhead projector and modeled a trial and error approach. Throughout the enactment, students used that approach; for each blank in the puzzle they tried both multiplication and division.

Student Communication. Teacher-participants enacted independently planned lessons that allowed students to collaborate with one another. During Shantel's lesson on linear measurement and Keisha's lesson on multiplication and division puzzles, students were given tasks and materials and were assigned to work with specific partners. Both enactments included instances where students communicated their mathematical thinking with each other (level-three student communication). This occurred once during Shantel's measurement lesson with her AGL-1 class and twice during Keisha's lesson with multiplication and division puzzles. Three times during Shantel's lesson and six times during Keisha's lesson) teacher-participants prompted students to communicate their mathematical thinking (level-two communication).

While numerous opportunities for high-level student communication were provided, students most often shared answers with either classmates or the teacher (level-one communication). This type of communication occurred 19 times (59.38%) during Shantel's enactment and 25 times (65.79%) during Keisha's enactment.

Algorithms. Algorithm use only occurred during Keisha's lesson on the partial product algorithm for multiplication. Students watched Keisha work an example on the overhead projector. Consistent with the professional development instructional practices, alternative algorithms for multiplying numbers were introduced during workshops. However, Keisha's students were introduced to the algorithm by copying two already-completed tasks from the overhead projector into their notebook. Keisha then spent 5 minutes modeling how to complete the tasks using both the traditional and the partial-product algorithm. Following the modeling, Keisha assigned a task from the textbook which students attempted to complete using the partial-product algorithm. Students varied in their success; some solved the tasks without difficulty, while others used the new algorithm incorrectly and reverted to using the traditional algorithm.

Summary. A few of the independently planned lessons related to the professional development mathematics content and aligned with the TIM instructional practices. The aligned enactments included learner-centered components, such as student-directed tasks, the use of manipulatives, and alternative algorithms to complete multiplication tasks..However, most independently planned lessons were didactic and focused on students' computational skills or knowledge of mathematical definitions.

Independently Planned Lessons not based on Professional Development Mathematics Content

During the study, teacher participants completed eight enactments that were planned independently and not based on the professional development's mathematics content. Shantel implemented a total of seven enactments: three lessons each in her EIP class and an AGL class and an additional lesson in her EIP class. Shantel taught her three to her EIP and AGL classes during a three-week period during the third month of the study. During these enactments, Shantel's students' communication primarily occurred in response to her questions. Keisha developed and implemented a single lesson, during which students worked in pairs and discussed how to use the computer to make bar graphs.

Tasks. Task enactments included teacher-directed uses of manipulatives (level-two tasks). Keisha's students created bar graphs using the computer (level-two task). During Shantel's two enactments, students used calculators to find the mean and used square tiles to examine prime numbers (level-two tasks). During a lesson on decimals, one task was enacted as both level-one and level-two tasks reflecting students' use of a computer representation to support task completion. While these independently planned tasks provided hands-on experience, problems emerged during implementation. During Shantel's lesson on decimals, students worked independently on four tasks as she attended to another group who worked on a fifth task. Students working independently had access to manipulatives and technology, but did not successfully complete the tasks.

Technology. Technology use varied across implementations from teacher-centered uses (level-one) to student uses to support task completion (level-three tasks). Students used technology during three of the five lessons. Both teachers used overhead projectors and LCD projectors to model processes and present information to students. Keisha's students used an Internet-based program to generate bar graphs (Figure 4.11, http://nces.ed.gov/ nceskids/graphing); Shantel's students used Brainchilds and Playstations during a lesson on decimals and calculators during a lesson on the arithmetic mean.

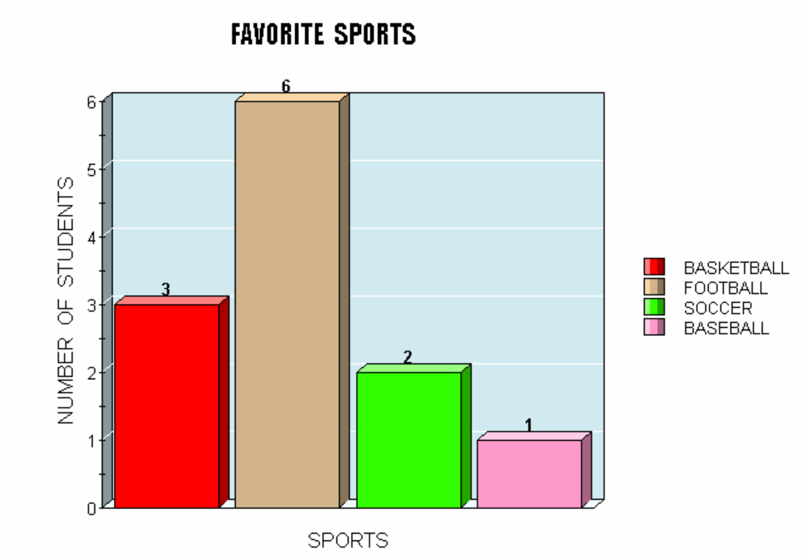

Figure 4.11: A bar graph created by one of Keisha's students.

During Shantel's first enactment of her lesson on multiples, she experienced problems using an LCD projector to display a website (Figure 4.12, http://www.harcourt school.com/activity/elab2004/gr5/8.html). After spending five minutes unsuccessfully attempting to address the problem, she read the tasks aloud and directed the class by posing tasks and asking students to share answers before moving to the next task.

Students wrote the tasks on notebook paper and participated by providing answers. Shantel downloaded the required software and used the website during the second implementation. The website provided answers in the form of a list of multiples and the least common multiple, which students read chorally as Shantel posed questions.

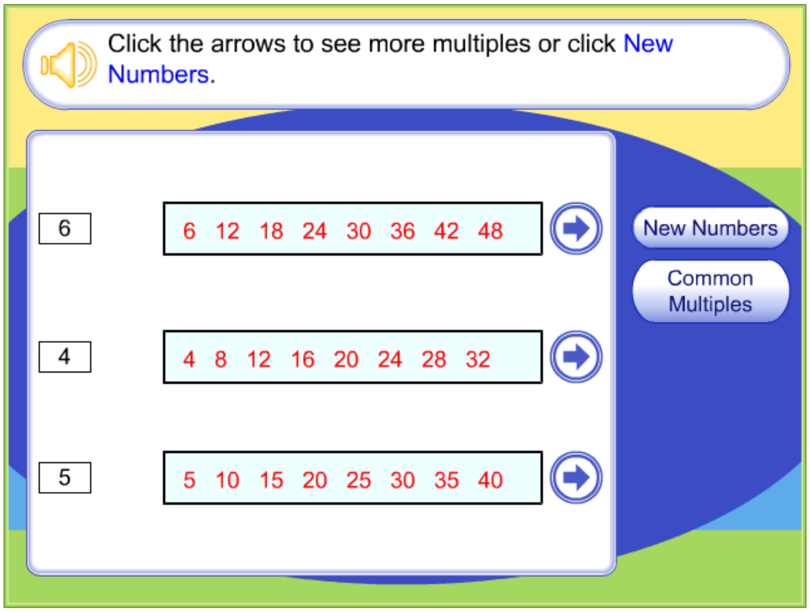

Figure 4.12: Website about multiples and least common multiples.

Algorithms. Algorithms were only emphasized during two of Shantel's lessons; the focus of the lesson shifted from the enacted tasks to becoming proficient at executing the algorithms' steps. During her lesson on adding decimals Shantel used an LCD projector to display tasks and virtual base-10 blocks that represented the addition problem. Shantel's comments and questions focused on the traditional addition algorithm, such as asking questions about the process of carrying numbers while she added. Shantel's intentions aligned with the workshop's intent to connect the virtual base-10 blocks to the algorithm they were using. However, her questions focused on the explicit steps in the algorithm rather than the relationship between the blocks and the algorithm. During her lesson on means, Shantel provided calculators for students to compute the mean of sets of numbers. After students completed the second task, Shantel asked about the algorithm she had taught earlier in the week. Since students were unable to provide an acceptable answer, Shantel required students to complete the remaining three tasks using paper and pencil. During her post-observation interview Shantel reported that taking away the calculators reinforced the algorithm required to find the mean.

Questions. Both participants posed numerous questions during their respective enactments. Consistent with other implementations, Keisha and Shantel examined students' papers and mathematical representations and posed questions. When Shantel enacted her lesson a second time, she increased her questioning about students' mathematical thinking (level-two questions). During the first enactment of her lesson on least common multiples, Shantel asked her EIP class 20 level-one questions (out of 26 opportunities, 76.92%) and posed no level-two or level-three questions; during her second enactment, she asked one AGL class 28 level-one questions (out of 54 opportunities, 51.85%) and 8 level-two questions (14.81%). Keisha primarily posed level-one questions during her only enactment. For 16 of 27 question opportunities (59.26%), she posed non-mathematical questions regarding computer use. The remaining question opportunities (40.74%) focused primarily on the numerical value of each bar in the graph (level-one).

Mathematical representations. Students generated various types of mathematical representations during implementations. Shantel integrated technology and allowed students to use a website to create bar graphs on the computer. A week earlier, students created survey questions and collected data from their classmates. Shantel used an LCD projector to demonstrate how to make graphs. Students then worked in pairs to generate their representation.

Keisha's students also generated mathematical representations during two lessons on prime numbers and decimals. Students used plastic square tiles and base-10 blocks to set up and support task completion. Her students also had opportunities to work with teacher-generated mathematical representations. During Keisha's initial enactment of her lesson on least common multiples, the website did not work; consequently, Keisha wrote numbers on the board for each task while her AGL-1 students wrote multiples and the least common multiple on paper. During the second enactment with her EIP class, Keisha typed numbers into the computer, which were projected onto the blackboard. After the numbers were projected, Keisha's students wrote answers on their paper.

Summary. Both teacher-participants enacted independently planned lessons, but they were not related to the professional development mathematics content. All but one implementation involved teacher-directed tasks that focused on algorithms. While some tasks were associated with project resources (e.g., manipulatives, technology), these resources were used to complete a procedure that the teacher provided. An exception to this trend occurred during Shantel's lesson on graphing, where students used a Web-based program to create bar graphs from survey data that they had collected.

Question Two:

How do teachers' enactments of the practices emphasized during learner-centered professional development compare with their espoused and intended practices?

Direct Adoption

Each participant implemented one lesson directly from the professional development activities. Appendix M provides an overview of participants' implementations. While the participants intended to enact lessons that were consistent with the TIM instructional practices, their implementations did not match their intent.

Mathematical tasks. Both participants enacted tasks in their classroom. Since Shantel reported that her students typically struggled with tasks based in real-world contexts, she and the professional developer co-planned division tasks that were contextualized in real-world situations. Her initial enactment, however, was not consistent with her intent. After observing difficulties in associating answer from the original context, she posed a decontextualized task. During her post-observation interview, Shantel discussed her AGL-2 class' difficulties:

> They can do some of the long division but it's hard for them to back track and now go back to working with the manipulatives to represent what they had on paper … they get the concept they know what they are doing but they don't know why they're doing it and they can't explain everything that they're doing.

Shantel's second enactment was better aligned with her intent and the professional development practices. Students used manipulatives to complete contextualized tasks using manipulatives, the traditional division algorithm, and Shantel facilitated a discussion related to the two approaches.

Keisha's sole task enactment in this category did not align with her intention. Keisha intended to have students create tangram pieces out of paper and construct tangram puzzles, but she was not able to print the directions from her computer. During the enactment, problems arose when Keisha provided students with too many tangram pieces. During the post-observation interview, she discussed the enacted tasks:

> They had two different [sets of tangrams] which I think kind of confused them.…I think if I would have stuck with one color and each bag contained 7 pieces maybe they would have had an easier problem making it.

Keisha recognized her students' trouble with two sets of tangrams, and hypothesized that task completion would have been easier if they had only one tangram set.

Algorithms. Shantel's teaching of the traditional division algorithm matched the professional development's intent during her second implementation. The professional developer had modeled how to connect the traditional division algorithm, a contextualized task, base-10 blocks, and an alternative algorithm. Shantel intended to use this approach, but her AGL-2 class struggled with using the base-10 blocks during the first implementation, and she neither discussed the tasks nor introduced the alternative algorithm. Once her EIP students demonstrated competency completing the tasks, she introduced the alternative algorithm and posed division tasks which students completed using the alternative algorithm. During her post-observation interview Shantel reported: "[The students are] more comfortable with the old fashioned way of doing it but I liked him [the professional developer] showing me this is what it looks like to teach a concept [differently]." Throughout various interviews both participants reported a desire to use "new strategies to reinforce skills." Keisha reported during her baseline interview that she used the book to introduce concepts and used hands-on activities to provide "different approaches" to reinforce those concepts.

Questions. Both participants' questions failed to align with the TIM instructional practices. Shantel acknowledged that she needed to pose more questions about students' thinking, while Keisha reported that her questioning was effective. Keisha reported that she questioned effectively despite primarily asking non-mathematical questions or asking students to identify shapes. Shantel reported that she needed to focus her questions more on students' thinking (level-two questions); she posed no questions about student thinking during her first implementation but asked six level-two questions during her second implementation.

During the model teaching, the professional developer posed questions that elicited students' thinking (level-two) and facilitated student-to-student discourse (level-three). While both teachers reported their intent to mimic these questioning strategies during classroom implementation, the enacted questions focused primarily on a mathematical answer or a definition (level-one). Shantel's questions focused on the traditional long division algorithm steps and answers to basic division facts. During her post-observation interview, she identified differences between her intended and enacted practices: "I really feel like they [students] didn't take in what we talked about yesterday … I do need to question them more on what it is that they think that we're doing or what I'm saying to them." Keisha asked about the shapes needed to complete tangram puzzles. After Keisha's enactment, she espoused confidence in questioning: "I think I did very well. I didn't just come over and say 'no that's wrong'." Keisha's espoused and enacted practices aligned were consistent with the TIM instructional practices. She viewed her questioning as effective since she posed questions rather than telling students whether they were correct or not.

Technology and mathematical representations. Shantel's use of the projector aligned with both the professional development's intentions and her espoused practices during both enactments—more so in her second than her first implementation. Shantel used an overhead projector to model how to use base-10 blocks to set up and complete division tasks. During her first implementation, as Shantel modeled while her AGL-2 class observed, her students experienced problems recreating the representations. After the first enactment, Shantel modified the second enactment by using the overhead projector to further "break down [the process] for them and try to explain [how to use the base-10 blocks].” During the second enactment, Shantel modified her modeling and had her EIP students recreate her representation with base-10 blocks on their desk as she modeled. After mimicking Shantel’s work at their desks, her EIP students were able to solve the division task using manipulatives with fewer difficulties than her AGL-2 class. After her second enactment, Shantel indicated that students had more success when they were engaged during modeling by mimicking her representation on the overhead projector. This practice of modeling, while students were engaged in the process, was consistent with the professional development instructional practices. Students worked at their desk and their actions were scaffolded by the teacher who modeled specific processes.

In contrast to the practice modeled during professional development workshop, Keisha did not model how to complete tangram puzzles during her implementation. Her students immediately began working without an explanation or model to support task completion. During her post-observation interview Keisha commented:

> If I were to [teach the lesson] over I probably would have chosen a simple animal, and as a class everybody would make their own but we would be making the same one as I made it on the overhead, and then after that task then I think I would have let them choose their own picture.

While Keisha’s actual lesson was not aligned with her intended practice, she recognized the need to provide a model for her students.

Summary. Both participants experienced difficulties while enacting learner-centered tasks that had been directly adopted from professional development activities. Despite the learner-centered nature of the tasks’ designs, both teachers focused on algorithms or mathematical terminology in a manner that was not consistent with the professional development practices. The participants’ reported barriers that faced during implementation and discussed how they could address them in future lessons. For example, after her first enactment Shantel reported a need to ask additional questions about her students' mathematical thinking; during her second enactment, she posed more high-level questions.

Co-planned Lessons based on Professional Development Mathematics Content

Keisha enacted two lessons based on the professional development's mathematics content that she co-planned with the professional developer. While Keisha's first implementation was not consistent with the professional development practices, her second implementation was consistent and included numerous learner-centered characteristics. Shantel did not enact any lessons of this type.

Tasks, algorithms and mathematical representations. Keisha's enactments shifted from skills-based tasks without resources (level-one tasks) to conceptually-oriented tasks that allowed students to use materials and choose their own approach to support task completion (level-three tasks). Her first enactment included skills-based tasks but neither manipulatives nor technology and focused on using the traditional multiplication algorithm. Keisha intended to enact five multiplication tasks (Appendix M): two that the professional developer co-planned with her (level-two tasks) and three skills-based tasks (level-one tasks) she described as being approved: "[The professional developer] told me I could have some skill and drill [tasks]."

In addition to the three intended skills-based tasks, and contrary to the professional developer's recommendations, one co-planned task became skills-based. According to Keisha, the professional developer advised having students write word problems for multiplication tasks. While the enacted tasks were not aligned with the learner-centered professional development workshop practices and did not include word problems, Keisha stated, “It was a great way for them to do 2-digit times 1-digit [multiplication].”

During Keisha’s second co-planning implementation, students generated their own multiple representations and used both traditional and alternative algorithms to calculate numbers. During her post-observation interview, Keisha stated that the lesson helped students to “see [that] using addition and multiplication are basically the same because you come up with the same answer.”

Student communication. Student communication became increasingly aligned with the professional development, as evident in discourse on the processes and approaches to completing tasks (level-two and level-three student communication) rather than simply sharing answers (level-one student communication). Keisha reported after her first enactment that students benefited from sharing answers with each other. Following her second enactment, Keisha’s stated that she had facilitated communication by creating opportunities for “students to talk about solving the problems.” In both cases, Keisha’s stated approaches matched her actual practices; however, student communication during her second enactment aligned more clearly with the professional development instructional practices.

Technology. Technology was used only during three of the five tasks in Keisha’s first enactment. The Factor Game (Figure 4.6) was the only enacted task that was consistent with the professional development technology integration practices. Prior to the lesson, she reported her intent to use technology to “teach [multiplication] skills in different ways.” While students used technology during three of the five tasks, only one (the factor game) provided a tool or mathematical representation for students use. Keisha espoused that the Brainchild, which did not support task completion, was the most effective because students received instant feedback: “[Students] knew right then and there whether or not [their answer] was correct or incorrect so they didn’t have to wait.” While Keisha stated that Brainchild was an effective use of technology, the application was not consistent with the professional development technology practices to facilitate students’ task completion.

Questions. Keisha’s descriptions of her questioning strategies became increasingly aligned with her implementation across enactments. During her first enactment, Keisha posed questions about students’ answers, tending to supply information rather than pose questions. Afterward, Keisha reported that she questioned students with metacognitive prompts: “[I gave students a little helping hand … [I was] not so much as telling them the answer but saying, ‘What questions should you ask yourself?’”

In contrast, Keisha’s espoused questioning was more closely aligned with her enacted questioning and the instructional practices of the professional development during her second enactment, where she posed 11 questions related to students’ mathematical thinking. Keisha reported that she questioned “ineffectively” when one student repeatedly interrupted as she attempted to facilitate a discussion among students. Keisha reported that her effective questions (e.g., “What does area mean?”) prompted students to explain their mathematical thinking. However, her students typically responded with formulas, such as “area equals length times width.” When this occurred, Keisha accepted the students' response and proceeded rather than posing follow-up questions regarding their understanding.

Summary. Keisha's co-planned implementations included didactic, skills-based tasks during her first enactment and student-directed, concept-focused tasks during her second enactment. While her first implementation did not embody the professional development practices, Keisha reported her belief that the lesson was consistent with the emphasized pedagogies. During her second lesson, her espoused practices aligned with both her enacted practices and the TIM pedagogies.

Co-planned Lessons not based on Professional Development Mathematics Content

Shantel implemented a lesson about decimals that she had co-planned with the professional developers (Appendix M). Shantel taught the lesson three times (once with her AGL-1 class, and twice with her EIP class) at the end of the study. Shantel's third implementation was most closely aligned with her espoused practices and the professional development's intended practices.

Tasks and mathematical representations. Despite Shantel's intent to enact the same tasks in her EIP and her AGL-1 classes, the implementations varied across classes. She reported that the goal for both classes was to "talk about equivalent decimals so that we could line up decimals…the whole point was getting them to line up the decimals because we're [preparing to start] adding and subtracting decimals." Shantel's EIP enactment matched her initial intentions, but students experienced difficulties completing the tasks with manipulatives (level-two tasks). During her post-observation interview, Shantel reported: "I hadn't planned on spending that much time on base-10 blocks with my EIP students, but I did see that it was necessary … It seems that in just that one day they lost it." Shantel subsequently modified the task for her AGL-1 class., and students did not use manipulatives (level-one tasks). During the post-observation interview, she stated "My [AGL-1] class didn't need to start with the base-10 blocks. They already could do that." This class progressed faster than the EIP class and spent the end of the lesson working on computer-based decimals tasks in the computer lab. Shantel's EIP class did not go to the computer lab until the second day of the lesson.

Technology. Shantel's technology use during the first enactment matched her intentions but did not align with the professional developer's recommendations. The professional developer recommended a website that modeled traditional algorithms (Figure 4.8); only half of Shantel's students worked on that website.

> With my strugglers I wanted them to try the easier AAA math so they would have some success …The other ones that were already [on the recommended website] they're having success with decimals and they should get to go ahead and see some regrouping. See how cool it is that the computer lets them see how [the website] regroups the number and they can see it.

When Shantel's EIP class eventually worked in the computer lab, students used the recommended website. Shantel reported afterward that the website helped her students "see the addition and subtraction" and the representation on the computer. Technology use during Shantel's third enactment was better aligned with the TIM instructional practices; students used the tool to complete the tasks.

Questions. Shantel's actual questioning strategies were not consistent with either her espoused practices or the professional development practices. Most questions asked for only an answer or a definition (level-one questions), such as "What was your answer?" or "What number is in the tenths place?" Following her second enactment, Shantel commented, "I think my questions are getting them to think about their thinking.

I have better questions now than I did. In the beginning I would give them the answer… I can steer them in the direction I want them to go in better now because I'm thinking about what I want them to think about." Shantel's questioning improved across enactments and had become more closely aligned to the professional development instructional practices, though most of her questions continued to elicit simple answers rather than mathematical reasoning.

Algorithms. Shantel's enactment differed from her intent; students working on the recommended website did not relate the computer-based task to the traditional addition and subtraction algorithms. During her final enactment with her EIP class, Shantel asked questions including, "Where are you going to get more thousandths from? What do you need to do?" Some students used the traditional subtraction algorithm, starting at the right and working towards the left; others started in arbitrary columns and began working with the virtual base-10 blocks.

Shantel's algorithm use aligned with the professional development practices; however, students were unable to relate the tasks to the algorithms. Shantel reported that she attempted to help students to connect the virtual base-10 blocks to the use of algorithms. During her post-observation interview, she described a student who subtracted the numbers in only the thousandths place and moved to a new task: "she didn't see it as a math problem as far as the actual base-10 blocks. I don't know what she thought the numbers were."

Summary. Across Shantel's three co-planned enactments, the tasks and questioning strategies became increasingly consistent with the professional development practices. While her espoused practices during the first two implementations did not match the TIM instructional practices, her third enactment was consistent with the professional development pedagogies. While Shantel's practices became increasingly learner-centered; she continued to emphasize didactic components, such as explicitly providing procedures for students to follow and asking students to recite algorithms orally.

Independently Planned Lessons based on Professional Development Mathematics Content

Keisha and Shantel both independently planned and implemented lessons related to the professional development's mathematics content (Appendix M). Shantel taught one lesson to both her EIP and one of her AGL classes and one lesson to only her EIP class, while Keisha enacted three lessons with her students.

Tasks and mathematical representations. Teacher-participants' enacted tasks and mathematical representations were consistent with the professional development practices for five of the six implementations. These enactments included manipulatives and mathematical representations to support task completion (level-two and level-three tasks). During her lesson on triangles Shantel's intentions shifted and became focused on measurement skills rather than the properties of triangles. During the post-observation interview, Shantel discussed the benefit of incorporating measurement into the task: "[The rulers] added accuracy. You can eyeball [the side lengths], but it was better to use the tools." While Shantel's intended focus shifted during the lesson from triangles to measurement, she espoused that her students "benefited from [measuring the triangle's sides]."

Keisha's two independently planned lessons were consistent with the professional development intent of teaching "different approaches of how to [multiply]." Both of these lessons included teacher-directed skills-based tasks (level-one tasks) for the first 30 minutes. During the last fifteen minutes of each implementation, students completed tasks related to the mathematical goals of the lesson. These tasks were also teacher-directed; Keisha provided explicit directions about how to complete the task. During the post-observation interview following her first implementation, Keisha reported: "I can't expect all [my students] to sit there and learn the traditional way simply by doing the problem." Later in the interview Keisha called her implementation successful, because it provided a "different way for students to learn about multiplication."

Questions. Consistent with practices advocated and modeled during the workshops, participants stated that they posed questions related to students' mathematical thinking. Their enactments included several questions related to both student answers as well as student reasoning. Shantel questioned more about students' mathematical thinking during her first independently planned lesson (on triangles) than subsequent lessons of the same origin (enactments about linear measurement). Following her first implementation, Shantel reported that she did not initially intend to pose many questions but did so when students were erroneously measuring the triangle's sides because she "couldn't account for why their numbers weren't coming out the same" and wanted to "see what was going on." Shantel's espoused practices of posing numerous questions about students' mathematical thinking aligned with her classroom practices and the intent of the professional development. In contrast, during her lessons on linear measurement, Shantel primarily asked students which unit was appropriate for each object. While she occasionally followed-up and asked students to justify their answer, Shantel typically asked pairs of students a question before moving on to another pair.

Keisha's questioning strategies improved across the three implementations. Further, her enacted and espoused questions became more closely aligned with practices embodied in the professional development. During her first lesson (array models of multiplication) no instances of questioning for students' mathematical thinking were apparent despite her statement that she "asked students about what they were thinking." During her third enactment (multiplication and division puzzles), Keisha asked students about their mathematical thinking but still asked a lot of questions about students' answers. Keisha stated that her "role was to just go around the group and see how they were thinking about it and what kind of strategies they used." While several questions continued to focus on students' answers, she also posed six questions about students' mathematical thinking.

Technology. Consistent with the professional development, teacher-participants intended to and used an overhead projector to model processes during implementations. However, the projector was not used consistently with the workshop practices. Rather, enactments were teacher-directed; student activity was limited to copying information into notebooks and replicating the triangle being displayed.

The only instance of student technology use that aligned with the professional development occurred when Keisha's students used calculators to complete multiplication and division puzzles. During the lesson, students typically employed a trial and error approach that Shantel had modeled at the beginning of the lesson. Following her implementation, Keisha reported that the calculator was an effective tool because it did not do the work for the students: “The calculator gave them the answer. [Students] still had to think about what operation they wanted to use.”

Student communication. Contrary to the professional development instructional practices, Shantel’s students simply shared answers with each other. However, students shared their mathematical thinking when Shantel posed questions such as “Why do you think that unit is most appropriate to measure the pencil?” During one discussion, students looked for patterns in a list of the conversions for 1 meter (e.g. 1 m = 1000 mm, 1 m = 100 cm, 1 m = 10 dm). Shantel noted one student’s comments about the pattern during her post-observation interview: “She was working harder than I expected any of them to work. What I wanted them to do was regurgitate what had been given to them, and she went above and beyond.” When Shantel prompted students to share their mathematical thinking, her espoused student communication practices aligned to both her enacted and the professional development practices. However, when Shantel did not query, students did not share their mathematical thinking and the goal of supporting student-to-student communication about mathematical thinking was not evident.

During Keisha’s lesson on multiplication and division puzzles student communication was consistent with the professional development. Keisha reported during her baseline interview that collaborative activities are effective because, “kids understand other kids better than they do the teachers.” Students shared ideas about how to complete the puzzles and used the calculators to test their approach.

Algorithms. The only intended use of algorithms occurred when Keisha “reinforced multiplication skills” during a lesson on the partial product multiplication algorithm. Her intent to use alternative algorithms was consistent with the professional development, but Keisha's enactment did not align to the TIM instructional practices. Keisha instructed students to copy two completed tasks that used the algorithm, then modeled how to use the algorithm to complete one of the tasks. Keisha reported during the post-observation interview that students had effectively learned the alternative algorithm by "copying down examples of the algorithm" and "practicing it." Keisha described her desire to teach alternative algorithms: "If there is more than one method, I'm going to teach it because to me it's like the light may be on with one way and the light could be brighter with another way."

Summary. Although both teacher-participants implemented tasks that were aligned with the professional development practices, other practices were not. The independently planned lessons included opportunities for students to work with manipulatives to complete tasks. During the enactments, however, students also spent time copying algorithms and answering procedural questions. Both participants' self-reported practices were not consistent with the professional development practices. Teachers reported beliefs that the use of manipulatives, alternative algorithms and technology aligned to pedagogies that presented during the workshops.

Independently Planned Lessons not based on Professional Development Mathematics Content

Shantel and Keisha both independently planned and enacted lessons that were not related to the workshop mathematics content: Keisha completed one lesson and Shantel completed seven. The lessons were recorded since the participants reported that while the mathematics content was not addressed during the workshop, they intended to use instructional practices emphasized in the professional development. Enactments aligned with the workshop instructional practices during three of the eight implementations.

Tasks. Students used manipulatives or technology to complete level-two and level-three tasks during six of eight enactments. Shantel's lessons on prime and composite numbers aligned with both the TIM instructional practices and her espoused practices. During the post-observation interview, she reported that she valued the hands-on tasks because they provided "a concrete experience for a concept that is typically abstract." Keisha's implementation also matched the intentions of the professional development; students used a Web-based tool to create bar graphs from they had collected a week earlier.

However, Shantel's lessons also included tasks not aligned to the professional development instructional practices. For example, during her lesson on decimals Shantel set up five skills-based tasks. Three of these tasks involved adding decimals on paper using the traditional algorithm: students completed tasks that they read from a Brainchild, an LCD projector, or computational tasks that they created using prices from a grocery store advertisement. Technology and real-world contexts were both emphasized during the professional development; however, the tasks were implemented in a teacher-centered manner, in which the technology supported the teacher's presentation of materials (e.g., an LCD projector), but was not available for students to use. During her post-observation interview Shantel stated that the lesson "let [my students] see decimals in many different ways."

Technology. Consistent with professional development practices, technology was used to support task completion during two of the eight enactments (Keisha's lesson on bar graphs and Shantel's lesson on mean). During five other enactments, technology was integrated, but not consistent, with the TIM instructional practices. For example, during Shantel's lessons about decimals, students used Brainchilds to generate tasks and receive feedback; they also used Playstations to generate and complete tasks with the joystick. Students also referenced a projected representation of virtual base-10 blocks to scaffold their addition work, while at other times the technology displayed feedback for students' paper work. During the post-observation interview, Shantel stated that the website "allowed me to punch in those numbers and have it [projected so] they can see it. It doesn't just have the numbers right there it has the actual [base-10] blocks that illustrate [the task]." Shantel valued that she could display both the addition task and the base-10 blocks on the screen; she referred to the base-10 representations occasionally during implementation, but more frequently only used it as a mechanism to check students' answers.

During Keisha's lesson on bar graphs, technology use aligned with her intentions; students used a web-based tool to make bar graphs from survey data that they had collected a week before (Figure 4.11). During her post-observation interview Keisha reported her intentions for the lesson to be a "refresher on bar graphs." Students had already graphed the data on poster board, but Keisha "wanted [students] to make a bar graph using technology."

Algorithms. Algorithms were incorporated into Shantel's lessons on mean and decimals but not consistently with the professional development instructional practices. During both enactments, Shantel explicitly reminded students about the steps, asked specific questions about the steps and had students orally recall the steps of the algorithms. Both enactments included hands-on tasks to accompany the algorithms, but students' use of resources was dominated by paper-and-pencil used to apply the algorithms. Students were unable to recall the steps of the algorithm that Shantel had taught related to the mean, so Shantel removed calculators and had students complete the remaining tasks using paper and pencil. During her post-observation interview after her lesson on mean, she shared her intended goals for the lesson: "I wanted them to actually be able to [find the mean on paper] because when it comes time to actually take the [CRCT] test there is no calculator and I want them to have success with the [CRCT] test."

Questions. Participants' questions varied as to the distribution of questions focused on answers versus mathematical thinking. When Shantel enacted the same lesson in both her EIP and one of her AGL classes, her questions focused on students' thinking across enactments. Her initial enactments typically included direct questions (e.g., "What is your answer?"), while subsequent enactment questions focused on reasoning (e.g., "What does your answer mean?"). After implementing her lesson on decimals, Shantel stated that she questioned effectively, explaining that she "wanted to see if they could do [the tasks] and see what their thinking was. I wanted them to understand … "what is regrouping?" "What does that look like?" "Why are we doing it?" Shantel's questioning strategies aligned with her intentions, the TIM instructional practices, and her self-described practices for the second enactment of lessons that were repeated.

Keisha's questions did not align closely with the TIM instructional practices. While students created bar graphs on the computer, Keisha's questions focused on the explicit steps needed to make the graphs and the numerical value of the bars in the graphs. During the post-observation interview, Keisha reported that she questioned in order to "reinforce concepts" that students practiced.

Mathematical representations. Teacher-participants' use of mathematical representations was consistent with the professional development instructional practices and their espoused practices during Keisha's only implementation and Shantel's enactments on prime and composite numbers. During Shantel's lesson on prime and composite numbers, students generated multiple representations to support task completion (level-three representations). In Shantel's other enactments (i.e., decimals and least common multiples), her representational use of the LCD projector was not consistent with the practices emphasized during professional development. The website used during the least common multiple lesson listed all multiples and identified the least common multiple; students read the answers and transferred them to their work sheets. During her post-observation interview Shantel reported that the website let students "see numbers that were common multiples and the least common multiple." While multiple representations were advocated during the workshops, Shantel provided answers rather than supporting task completion.

Summary. Lessons that were independently planned but unrelated to the professional development mathematics content aligned to the professional development practices for three of the eight implementations. Both teachers implemented tasks that included manipulatives or technology; however, teachers provided students with explicit directions on how to complete the task. Teachers' espoused practices were not consistent with their enacted practices. They believed that their lessons were aligned to the professional development since they used manipulatives, technology or tasks based on real-world scenarios.

Question Three:

How does evidence of student understanding reflect teachers' enacted practices?

Evidence of student understanding was obtained in three forms: mathematical representations that students used to complete the tasks, student communication about tasks or mathematical ideas related to the tasks, and students' representation of their mathematical work. Data from classroom implementations (video and field notes) were the primary data sources for this question.

Lower-level task enactments did not include mathematical representations or representations generated by either the teacher or the computer and were not used to support task completion. Student communication during lower-lever enactments involved sharing answers but not discussion of mathematical thinking. In contrast, when teacher-participants implemented high-level tasks consistent with the TIM instructional practices students used teacher-generated or student-generated mathematical representations to help complete tasks. Further, student communication included discussions of solution strategies and mathematical thinking as well as answer sharing.

Types of tasks

Based on analysis of classroom implementation (video and field notes), participants enacted 37 task types. Chapter 3 defined task types for the purposes of the present study. Table 4.2 lists the enacted task types by task gradient for each teacher-participant and class.

Table 4.2: Enacted task types organized by the task's gradient

Teacher	Class	Tasks without resources and a teacher-directed approach	Tasks with resources and a teacher-directed approach	Tasks with resources and a student-directed approach
Keisha		6	3	2
Shantel	EIP	4	7	2
	AGL-1	3	3	1
	AGL-2	3	3	0
	Total	16	16	5

Teacher-directed Tasks without Resources

A total of 16 task types (43.24%) did not align with the professional development instructional practices. During implementations, students followed teacher procedures (level-one tasks) and did not use manipulatives or technology to support task completion. These low-level tasks focused on computational skills and the correct use of algorithms. Keisha enacted six of these tasks, four during a lesson on multiplication, and two during a lesson on the partial-product algorithm. Shantel enacted the other ten tasks; half of them during two implementations of her lesson on decimals.

Mathematical representations. Teacher-participants provided teacher or computer-generated mathematical representations to support task completion during 4 of the 16 level-one tasks. Seventy-five percent of the level-one tasks enacted did not include mathematical representations, and were not consistent with the TIM instructional practices. The enacted tasks included both teacher-directed tasks, where the teacher posed a task orally, and tasks in which the students read a problem from paper or a computer and solved it using a traditional algorithm. For example, during one of Shantel's least common multiples lessons with her EIP class, she displayed a computer-generated list of multiples via an LCD projector. Students worked at Shantel's pace repeating the answers displayed and mirrored the representation to respond to Shantel's questions.

Student communication. Students communicated answers orally with their teacher but rarely discussed their mathematical thinking. Communication was prompted by teachers who posed questions about students' answers or the explicit steps in an algorithm that was used (e.g., the traditional algorithm for multiplying a two-digit by a one-digit number). During a few level-one tasks aligned with the professional development, students shared their mathematical thinking. For example, during Shantel's lesson on equivalent decimals, her AGL-1 students responded to questions and explained their approach to finding equivalent decimals for roughly one-fourth of the student communication opportunities. Shantel facilitated these opportunities by posing questions such as, "If I wanted to change the value of my decimal by adding a zero, where would I put the zero?" Still, most level-one tasks either provided opportunities for students only to share an answer or a mathematical definition (level-one) or did not provide communication opportunities.

Students' representations of mathematical work. Evidence of students' mathematical work typically consisted of a calculation or answer on paper. Shantel's students were not required to record work during tasks where technology generated problems (e.g., Brainchilds and Playstations). However, they showed their work and solutions for the other task types, using traditional algorithms to complete tasks. Keisha's students did not record mathematical work during two of her six task types involving playing a board game and using flash cards to develop students' knowledge of multiplication facts. For the other four enacted task types, students wrote out their computation and the solution to multiplication tasks.

Summary. Enactments of teacher-directed tasks without resources (level-one tasks) were associated with either no mathematical representations or representations the teacher generated on either the blackboard or computer. Students completed these tasks using algorithms and student communication was limited to sharing answers or steps of a procedure with teachers or classmates. Students' representations of mathematical work during these tasks consisted of writing a computation and a solution.

Teacher-directed Tasks with Resources

Sixteen (43.24%) enacted task types included resources (technology or manipulatives) and teacher-directed approaches to support task completion (level-two tasks); Shantel enacted 13 of these tasks, while Keisha enacted 3. Level-two task enactments led to student-generated mathematical representations, student communication that included both answers and students' mathematical thinking, and mathematical work that included computer-generated and manipulative-generated representations as well as traditional computations on paper. For example, when Keisha's students created array models of multiplication on construction paper students made their array and used the traditional algorithm to complete the computation on paper.

Mathematical representations. Of the 16 task types, 3 included only a teacher or computer-generated representation, 11 included one student-generated representation, and 2 included multiple student-generated representations. Keisha's factor game (Figure 4.6) and Shantel's website lesson on adding and subtracting decimals (Figure 4.8) featured computer-generated representations to complete the tasks. Students used a variety of materials (e.g. base-10 blocks, geoboards, calculators, and rulers) to generate representations while completing level-two tasks but experienced difficulties using the representations to complete the tasks. While playing the factor game, Keisha's students did not read the directions and were often off-task. During Shantel's students' use of the decimal website, students were unable to solve the task; they moved the virtual base-10 blocks on the screen but did not complete the task.

Students generated a mathematical representation during 11 of the 16 level-two tasks. During Keisha's lessons, students used a website (Figure 4.11) to create bar graphs from data that they had collected a week earlier. They also made array models of multiplication on construction paper. Shantel's students used a variety of manipulatives, including geoboards, base-10 blocks and calculators, to support task completion. According to Shantel, she examined students' work to gauge their understanding.

Two task enactments yielded multiple student-generated representations. During Shantel's lesson on prime and composite numbers, both her EIP and her AGL-2 class generated multiple arrays for a given number of tiles. When Shantel asked, "Can you make any more arrays?" students initially insisted that there was only one possible representation for every number until Shantel prompted students further. When Shantel prompted students they frequently insisted that no more arrays could be made. Shantel told students to "look more closely" and then moved onto question other students. While multiple representations were advocated during workshops, students had difficulty generating multiple arrays during implementation. Even with Shantel's prompting, students insisted that only one array was possible.

Student communication. Student communication varied during teacher-directed tasks involving students' use of resources (level-two tasks). Consistent with the professional development, students worked in pairs and communicated with each other during Keisha’s lesson on creating bar graphs; however, all student-to-student communication focused on procedures regarding technology use. Keisha’s students took turns using the mouse and discussed the process of entering in data, the orientation of the graph and the colors of the bars. Keisha asked questions related to the graph such as, “What does this bar represent?” and “What is the scale of your graph?” These questions focused discussions more on the mathematics, but did not yield evidence of students’ mathematical thinking.

During the other level-two enactments, student communication focused on responding to teachers’ questions. At the beginning of the study, Shantel’s students used base-10 blocks to complete division tasks. When she asked students to explain their work, students did not relate the base-10 blocks back to the traditional division algorithm. However, during certain enactments, teachers posed effective follow-up questions that encouraged students to justify their answers and explain their thought processes. For example, during Shantel’s lesson on triangles, her EIP students had erroneously measured the lengths of the sides of a triangle. Students responded to Shantel’s questions and shared their answer and their reasoning.

Students’ representations of mathematical work. During level-two enactments, student representations featured manipulatives and hand-written solutions for mathematical work. Shantel’s students made representations from various manipulatives (e.g. plastic tiles, base-10 blocks, geoboards) as she projected the algorithm via an overhead projector. Students also used computers to manipulate virtual base-10 blocks (Figure 4.8). Keisha’s students made bar graphs on the computer. Students also displayed mathematical work on the computer during some level-two task enactments. Her students watched as she modeled the use of a web-based graphing program (Figure 4.11) and then generated their own computer-based bar graphs. While enactments included teacher-directed approaches, students used manipulatives and technology to generate numerous representations of their mathematical understanding. These uses of manipulatives and technology embodied the professional development instructional practices.

Summary. The implementation of tasks using resources (level-two tasks) included mathematical representations generated by either the teacher or by students under the teachers' explicit direction. Although these tasks included manipulatives, they focused on students' skills and the use of algorithms. During implementation, students occasionally communicated their mathematical thinking with the teacher. Students' representations of mathematical work included representations generated using the manipulatives or technology as well as computations and solutions on paper.

Student-directed Tasks with Resources

Five of 37 enacted tasks types (13.51%) included student use of manipulatives or technology and student-directed approaches to support task completion (level-three tasks). Keisha enacted three of these tasks, while Shantel enacted two. These were the only instances during the study where students chose how to complete the tasks, an approach that was discussed and modeled during the workshops. During the implementation of student-directed tasks, students generated mathematical representations and evidence of their mathematical work. Further, student communication during these level-three tasks tended to focus more on students' mathematical thinking than lower-level task types.

Mathematical representations. All enacted task types aligned with the instructional practices emphasized during the professional development; students used concrete materials to generate representations to support task completion. Student representations were evident during the lessons when students used calculators, measurement tools and plastic square tiles to carry out an approach that they had developed. For example, Keisha's class engaged in level-three tasks when they used plastic square tiles to measure the area and perimeter of rectangular shapes chosen by the teacher (Figure 4.4). Shantel's level-three enactments allowed students to identify classroom objects and identify appropriate units of measurement. Student understanding was evident in their use of manipulatives to complete the tasks and in the computations and written answers.

Student communication. During student-directed enactments, students also shared their mathematical thinking with other students (level-three student communication). Four of five enactments included student-to-student discourse about the process of completing tasks. Shantel's students worked in pairs during her implementations about linear measurement. Despite working on similar tasks, AGL-1 students discussed their mathematical thinking (level-two student communication), while EIP students only communicated answers (level-one student communication). The differences across implementations were influenced by Shantel's questioning strategies. During her baseline interview Shantel stated that she enacted a teacher-centered approach with her EIP class compared to her two AGL classes. Shantel asked her AGL-1 class to explain their reasoning for selecting specific classroom objects (level-two student communication).

Shantel asked her EIP class to name the objects that they selected, but did not ask them to explain their reasoning.

During Keisha's lesson on area and perimeter, she organized students into groups of four and instructed them to discuss possible approaches and agree about how best to find the area and perimeter of rectangular shapes around their classroom. During her lesson on multiplication and division puzzles, she assigned students to work in pairs, exchanging ideas and using calculators to solve the puzzle.

Students' representations of mathematical work. Consistent with the professional development, during four of the five level-three enactments, students worked with tactile materials and then represented their mathematical work on paper. During Shantel's lesson on measurement, students recorded on paper classroom objects they had identified using the measurement tools. Keisha's students wrote out the calculations and the area and perimeter of the rectangles they had previously measured after using plastic square tiles; then wrote their answers on the chalkboard. During her lesson on multiplication and division puzzles, students used the calculator to facilitate task completion. After solving a puzzle, they wrote the solutions on the worksheet provided. Keisha's tangram lesson was the only task where students did not represent their work on paper. Students worked on tangram puzzles during the enactment; when the lesson ended students put the tangram pieces away and had no representation for their work.

Summary. Student-directed tasks with resources (level-three tasks) provided opportunities for students to devise their own approach and use manipulatives to complete tasks. The mathematical representations associated with the tasks were all student-generated. During implementation, students collaborated with one another to complete the tasks. They shared answers, approaches as well as their mathematical thinking with each other. Finally, students' representations of mathematical work included work with manipulatives, computations and solutions.

Chapter V

DISCUSSION AND IMPLICATIONS FOR RESEARCH

The purpose of this study was to examine teachers' enactment of the instructional practices emphasized during learner-centered professional development, how their implementation compared to their espoused practices and the professional development's intended practices, and the extent to which student activity was influenced by teachers' enacted tasks. Several patterns warrant further discussion: 1) classroom implementations were largely unaffected by the professional development activities and tasks; 2) teachers began to enact learner-centered mathematics tasks and related instructional practices during the latter stages of the study; 3) teachers reported practices that were consistent with the professional development emphasized pedagogies, but their actual classroom teaching practices were not consistent; 4) several problems emerged while implementing and sustaining the few learner-centered practices that were evident; and 5) the nature of student work and activity was influenced by learner-centered classroom teaching practices. In this chapter, each of these patterns is described and discussed, several related findings are further described in the framework of the research, and implications for future research are provided.

Little evidence was found to indicate that participants' enacted practices aligned with the professional development intended practices. Consistent with prior research studies (e.g. Cognition and Technology Group at Vanderbilt [CTGV], 1997; Doyle, 1988; Henningsen, Stein, & Grover, 1996; Schneider et al., 2005), a majority of the enacted tasks did not align with the professional development instructional practices. Both teacher-participants implemented didactic tasks that did not include resources or used them for rote procedures rather than to complete the tasks. One explanation for teachers' enactments of low-level tasks might be their desire for their students to have success in mathematics. Previous studies about the enactment of mathematical tasks (Doyle, 1988; Henningsen, Stein, & Grover, 1996; Kim & Stein, 2006; Tarr, Chavez, Reys, & Reys, 2006) found that teachers often provided rote procedures, skills-based practice problems and explicitly told students how to complete the tasks in order to ensure students' success. During the present study, teacher-participants focused on computational skills and the explicit use of algorithms during tasks that were intended to extend beyond skills-based tasks. Shantel, for example, posed decontextualized division tasks after her students struggled to complete the first few high-level tasks that were posed.

The most surprising findings related to enactments that were well-scaffolded by professional developers, that is, tasks that professional developers either modeled or co-planned with participants. Contrary to expectations, although Shantel and Keisha had observed the professional developers implement the tasks, both taught didactically and focused on the use of rote algorithms to complete the tasks. Keisha's co-planned lesson focused on students' use of a traditional algorithm and student memorization of basic facts. The professional development goal, in contrast, was to extend beyond skills-based approaches to develop students' conceptual understanding and problem solving processes. Similar findings emerged from the *Jasper* project (CTGV, 1997); teachers provided students with skills-based worksheets and algorithms that redefined Jasper's learner-centered tasks.

Subsequent implementations were more likely to feature learner-centered tasks and high-level questions. Also consistent with prior research (e.g., Fennema et al., 1996; Kubitskey et al., 2003), as the study progressed both participants' enactments became increasingly aligned with the student-centered professional development pedagogies. Keisha's final two enactments and one of Shantel's final lessons included student-directed tasks that included resources (manipulatives or technology) to support task completion. These findings are similar to those reported by the Cognitively Guided Instruction (CGI) project, where teacher-participants did not implement tasks aligned to the professional development goals until the second year of the project (Fennema et al., 1996). Teachers in the LeTUS project implemented tasks that were consistent throughout the entire project, but experienced dilemmas integrating technology and supporting students' task completion during the first year of the initiative (Kubitskey et al., 2003).

Professional development researchers examining teacher questioning of students' mathematical thinking reported that teachers needed time to make substantive changes to their teaching practices (Richardson, 1994; Orrill, 2001) and to recognize instances where questioning would be appropriate (Sherin & van Es, 2005). In the present study, both Shantel and Keisha asked more high-level questions during their later enactments. The increase in high-level questions as the study progressed may be evidence of the cumulative impact of ongoing professional development activities. During the workshops, teachers observed high-level questioning strategies modeled by the professional developers, reading and watching teachers' implementation episodes and discussing questioning approaches. It seems likely that initial attempts to apply target strategies were influenced by limited familiarity and few opportunities to practice. While subsequently co-planning lessons, teachers were instructed to provide the professional developer with questions they planned to ask during implementation. Thus, with ongoing workshop and planning support, paired with prior opportunities to apply the methods with their students and emerging familiarity and comfort, teachers were more likely to demonstrate learner-centered practices in their classrooms.

Participants' espoused practices did not align with the professional development instructional practices. During this study, teachers' interpretation of the TIM instructional practices rarely matched the actual practices. While teacher-participants reported that each of their implementations would align with the professional development instructional practices, few were consistent. Prior studies reported similar results: researchers observed teachers as they employed didactic instruction, but teachers' indicated they were implementing reform-based mathematics instruction (Peterson, 1990; Wilson, 1990).

The interview data suggest that participants believed that their implementations were aligned with the professional development due to the use of resources or tasks taken from the workshops. For example, Keisha taught an alternative algorithm by having students copy the procedure and examples. During previous studies, teachers returned to their classroom and enacted professional development tasks and pedagogies didactically focused on the use of rote algorithms and procedures (CTGV, 1997; Peterson, 1992). While the teacher-participants adopted some learner-centered pedagogies and resources from the workshops, their enactment rarely aligned with the professional development instructional practices.

This disconnect may indicate that participants' professional development expectations may have differed from the TIM instructional practices. In prior research studies (e.g., Fennema et al., 1996; Peterson, 1992; Prawat, 1992), differences between teachers' espoused practices (what they thought they did) and their enactment (what they were observed doing) and the professional development instructional practices have been attributed to beliefs about mathematics teaching and learning. CGI teachers' instructional practices and beliefs became increasingly aligned with the TIM practices over the course of the study, but researchers were unable to identify whether beliefs or practices typically changed first (Fennema et al., 1996).

Prawat (1992) found that teachers adopted reform-based practices but only implemented those which aligned with their reported beliefs about mathematics teaching and learning. Accordingly, while implementation pedagogy became increasingly learner-centered as the present study progressed, few or no changes in associated beliefs were apparent. Teacher-participants reported their intent to implement tasks consistent with the professional development, but may have adopted those aspects they identified as being consistent with their deeply-held beliefs about teaching and learning.

Although scaffolding influenced classroom enactments, didactic components were evident even during highly scaffolded tasks. Tharp and Gallimore's (1988) application of Vygotsky's Zone of Proximal Development to teacher learning contended that teachers require extensive support and guidance when first learning new pedagogies. This support can be scaffolded and gradually removed when teachers are able to independently enact these new pedagogies. Studies of enacted curriculum (Remillard, 2005; Kim & Stein, 2006) found that teachers were more likely to implement learner-centered curriculum when instructional materials adequately supported instruction. The present study confirmed teachers' need for support; classroom implementations were most closely aligned with the professional development instructional practices on tasks that were scaffolded by the professional developers (i.e., tasks the professional developer modeled or co-planned with the participants).

However, while scaffolded task enactments included learner-centered attributes, participants continued to simplify complex tasks, direct rather than guide, and focus the tasks and their questions on computations and students' use of explicit algorithms. For example, Shantel asked low-level questions and explicitly reminded students about the steps during the enactment of a co-planned lesson about long division. During Keisha's co-planned lesson, she modified the task to the extent that her enactment no longer aligned with the practices being modeled.

Recent calls for school-based professional development programs suggest that teacher need ongoing support as they implement unfamiliar practices in their classroom (Sandholtz, Ringstaff, & Dwyer, 1997). While scaffolding task design (e.g., direct adoption, co-planning) increased the likelihood of implementing learner-centered tasks, teachers need support *during* implementation. Prior to implementation, the professional developer had modeled the same lesson and recorded Shantel's enactment of the lesson. However, no support was given during Shantel's enactment, which she was expected to teach independently, and Keisha received no on-site support during her implementation. In both cases, assistance during implementation might have alleviated the problems associated with the implementations. Shantel, who simplified tasks to support students' completion, might have benefited from co-teaching with a professional developer to provide a model about how to scaffold students' progress. Keisha, who modified the tasks by providing too many resources, might have benefited from real-time assistance in distributing resources and posing tasks.

Participating teachers may also have lacked a sense of ownership of their classroom enactment; their inclination to enact learner-centered classroom practices may not yet have been adequately reconciled with their well-honed mathematics teaching and learning beliefs and practices (Song, Hannafin & Hill, in press). Thus, they may well have modified them to accommodate their individually honed styles and preferences. Consistent with prior research (e.g., Battey & Chan, 2006; CTGV, 1997; Kim & Stein, 2006; Peterson, 1992; Wilson, 1990), Shantel and Keisha modified pre-designed and co-designed tasks and enacted them in a didactic manner. This lack of reconciliation between teachers' beliefs and the pre-designed learner-centered tasks may have engendered compliant task enactments that were nominally learner-centered, but implemented in a didactic teacher-centered manner.

Student work was influenced by participants' enacted tasks. During high-level task implementations that were consistent with the TIM instructional practices, related learner-centered evidence was apparent in mathematical representations used to support task completion and students' communication and representations of their mathematical work. High-level tasks as embodied during enactments were consistent with recent mathematics standards (GADOE, 2006; NCTM, 2000), recommendations from the mathematics education reform initiatives community (CTGV, 1997; Schoenfeld, 1992; Stein & Silver, 1996), and the professional development instructional practices.

During the present study, three types of evidence were observed: mathematical representations, student communication and students' representations of their mathematical work. High-level task implementations require the use of rich performance-based measures, such as the Balanced Assessment in Mathematics (Concord Consortium, 2006), to evaluate performance on tasks that require students to select an approach, complete computations, identify a solution and write an explanation that justifies their approach or makes generalizations about the tasks' mathematical concepts. Consistent with learner-centered professional development principles, students determined their approach, used resources, and discussed their work with their teacher and/or classmates.

Both teacher-participants applied aspects of the professional development in their classroom and implemented at least one high-level task that provided potentially rich evidence about students' learning. However, the pressure to maximize student performance of state and local criterion-referenced tests may have influenced participants to emphasize the accuracy of answers rather than mathematical reasoning. While the enactment of high-level tasks yielded evidence consistent with learner-centered assessment criteria and the Balanced Assessment materials, participants did not formally utilize this evidence. Both teachers examined student-generated mathematical representations and their mathematical work and asked students to share their answers and mathematical thinking but focused on whether students generated correct solutions.

Participants reported that learner-centered professional development was improving their mathematics teaching. Guskey (2000) cites the importance of examining participants' reactions during professional development; participants reported that the learner-centered professional development helped them both to think more deeply about and improve their mathematics teaching. While participants reported positive influences on teaching, their implementations typically did not align with the professional development instructional practices. Teachers have previously reported having a positive experience during professional development but were observed implementing practices that did not match the professional development pedagogies (Becker, 2003; Sandholtz, Ringstaff, & Dwyer, 1997).

This finding supports prior research about the validity of self-report related to teachers' instructional practices (D. Schacter, 1999; Ravitz, 2003). Historically, professional development studies have examined participants' reactions (Guskey, 2000). As evident in the present study, self-reported data is unreliable (D. Schacter, 1999); teachers often overstate the frequency with which they use the pedagogies emphasized during the workshop compared to actual observations of their classroom enactment (Buck Institute for Education, 2002; Mullens, 1998). It has become clear that professional development researchers need in situ observations and should extend data collection beyond only participant reactions.

Participants varied as to how they implemented learner-centered mathematics tasks in their classroom. Peterson (1990) and Wilson (1990) both found that teachers were willing to utilize new resources and manipulatives in their mathematics classroom but focused on mathematical algorithms and procedures in ways that reified their existing didactic practices. Accordingly, Shantel typically started mathematics units with hands-on tasks but provided explicit direction for students' actions, reasoning that students needed concrete support. Keisha introduced concepts by displaying information and giving examples of a completed task. Similar to *Jasper* teachers who provided students with worksheets to learn skills and algorithms prior to starting the tasks (CTGV, 1997), Keisha reported that her students could not use technology or manipulatives until they had learned the basic skills.

In addition to supporting implementation of learner-centered tasks, teachers' beliefs must also be addressed (Fennema et al., 1996). Keisha's view of concrete materials was at odds with the professional development instructional practices. She reported that her implementations reinforced the concepts students learned when they copied notes from the overhead projector into their notebook and completed computational tasks from the mathematics textbook. The professional development led to an increase in Keisha's use of resources and high-level tasks, but consistent with CTGV's (1997) findings, the use and impact of the resources were didactic rather than learner-centered.

Implications for Future Research

Scaffolding implementation. While the scaffolding tended to increase the likelihood of learner-centered task implementation, the teachers did not receive the type of progressive guidance recommended by Tharp and Gallimore (1988). The workshops transitioned from directly adopted, to co-planned to independently planned tasks, but participants varied in the order in which they implemented in their classrooms. Participants may have been more likely to adopt the professional development practices if their first implementation was directly adopted from workshops and subsequently followed by co-planned lessons and independently planned lessons. Perhaps initial enactments might be more effective if focused on directly adopted tasks modeled during the initial workshops and scaffolded via on-site support. Research is needed to examine the benefits and tradeoffs involved in explicitly imposing and scaffolding tasks developmentally. The current findings also support the need to scaffold learner-centered tasks *during* implementation, while their support needs emerge and can be addressed in real-time.

Clarifying links between the enactments and student learning. The current enactments of learner-centered tasks were associated with evidence related to student learning (e.g., student-generated mathematical representations, communication about students' mathematical thinking, and representations of mathematical work such as computations, diagrams, solutions, and explanations). Future studies should continue to examine how these pieces of evidence, and possibly others, are influenced by the enactment of learner-centered tasks.

The progressively scaffolded approach suggested previously may complement this line of research. Implementation of adopted tasks might promote consistent student learning outcomes (e.g., similar types of student-generated mathematical representations, communication about students' mathematical thinking, and representations of mathematical work). As teachers assume increased ownership of the implementations by co-planning and independently planning tasks and begin personalizing their approaches consistent with learner-centered tenets, student learning outcomes might then demonstrate greater variation. Research that attempts to link the implementation of learner-centered tasks to student learning outcomes must start by examining measures of student learning that are embedded within the tasks themselves (Reeves & Okey, 1996).

Employing design experiments to study and refine professional development. To the extent that the goal of research is to simultaneously advance theory and improve professional development practice, design research methodology may provide important benefits. The dynamic nature of research methods designed to optimize rather than only document practices appears well-suited to the goals of learner-centered professional development. Several research designs have the potential to examine projects in progress and use the data to impact practice and augment the effectiveness of LCPD projects. Design experiments' (Design Based Research Collective, 2003; Reeves, Herrington, & Oliver, 2005; Wang & Hannafin, 2005) approach to iteratively testing a theory, formatively evaluating data and making evidence-based decisions to refine the theory and impact practice aligns closely with the goals of learner-centered professional development research. In prior research (Fishman et al., 2003; Schneider et al., 2005), project personnel reported increases in the fidelity of implementation after modifying the professional development based on teachers' reactions and problems associated with co-planned lessons. During the current study, participants believed that their practices were consistent with the TIM instructional practices, while the implementation data suggested inconsistencies. Using design-based research methods, the project staff could access ongoing findings and modify the professional development and level of scaffolding based on the inconsistencies between teacher-participants' implementations and the professional development instructional practices.

Examining enactments and student learning longitudinally. Both professional developers (Loucks-Horsley et al., 2003; Sparks & Hirsch, 2000) and professional development researchers (Fennema et al., 1996; Fishman et al., 2003; Garet et al., 2002; Ringstaff, Sandholtz, & Dwyer, 1997) have advocated multi-year professional development projects. Researchers studying teachers in the CGI project (Fennema et al.,

1996) and the LeTUS (Fishman et al., 2003) did not report significant improvements in teachers' implementations and student achievement until the second year of the project. Further, students who were taught for three consecutive years by CGI teachers performed significantly higher than peers who had not been taught for three years by participating teachers. Clearly, professional development effects, fidelity, sustainability, and impact need to be examined systematically over a sustained period of implementation.

Examining effects on diverse mathematics outcomes. While student learning outcomes that are task-embedded provide rich data sources about the link between task implementation and students' learning, criterion and norm-referenced standardized tests also can contribute to our knowledge of student learning. Recent policies (see Georgia House, 2002; NCLB, 2002) mandate that teachers focus on improving students' scores on state-administered criterion-referenced tests. These assessments serve as a distal measure of the link between professional development, teachers' enactment of learner-centered tasks and student learning outcomes. If evidence can be generated that links learner-centered professional development instructional practices with a variety of student learning outcome measures, researchers may develop compelling arguments as to the complementary v. competitive nature of alternative pedagogies on different types of student learning.

Examining alternatives to teacher self-report. Consistent with prior research (Becker, 2003; Mullens, 1998), participants in this study reported that they enjoyed the professional development and intended to implement lessons that embodied the professional development pedagogies. However, the observations indicate that participants' implementations were not consistent with the intentions of the project.

Subsequent studies should continue to examine participants on multiple levels (Guskey, 2000), including participants' reactions, their implementation of professional development practices and student outcomes that are associated with the professional development instructional practices and teachers' enactments. Data sources during these studies should include self-reported data (e.g., surveys, interviews) and in situ data from the classrooms (e.g., video tapes, field notes, student work samples, student test scores).

Examining teachers' fidelity of implementation. Consistent with prior research (e.g., CTGV, 1997; Kim & Stein, 2006; Schneider et al., 2005), teachers in the current study did not implement pre-designed or co-designed tasks in a manner consistent with the learner-centered approaches emphasized and modeled during professional development. The pre-designed tasks included learner-centered components and provided opportunities for students to use resources, solve real-world tasks and collaborate with one another. However, both participants provided algorithms and focused on procedural knowledge during the enactment of the learner-centered tasks. Participants believed that their teaching was consistent with the professional development practices; however their enacted practices did not match their espoused practices.

Several factors may have influenced implementation, including external pressure to prepare students for the year-end criterion-referenced tests and insufficient time to design and implement tasks aligned with the professional development. However, consistent with Remillard's (2005) findings, individual factors such as limited content and pedagogical content knowledge, competing beliefs about teaching and learning, and limited experience implementing learner-centered tasks may also influence implementation of learner-centered tasks and associated pedagogies. Future studies should extend beyond determining simply whether or not teachers enacted professional development practices in their classrooms, and examine the mediating influences of external and internal factors that on fidelity of implementations.

Modifying the TIM-Teacher lens. The lens used in this study focused on TIM-Teacher professional development instructional practices. The lens gradients were developed using prior research studies (e.g., Fennema et al., 1996; Hufferd-Ackles et al., 2004) that employed rubric-like instruments to examine elementary school mathematics teaching, and ranged from no evidence to highly evolved evidence of learner-centered practice. During the current study, however, little variation was evident across the six filters, especially related to teachers' questioning and student communication. Future research should consider gradients that are more sensitive to the formative instructional practices of teachers beginning to enact learner-centered tasks. By using gradients sensitive to the incremental changes of novice teaching practices, the lens might prove better able to detect shifts in teaching practice.

Comparing the researcher's and teachers' perspectives. Consistent with prior research (e.g., Cohen, 2004; Orrill, 2001; Sherin & van Es, 2004), teacher-participants' instructional practices became more learner-centered as the study progressed. David Cohen's (1990) essay on Mrs. Oublier tells the story about a teacher who, in his opinion, has made minute shifts towards meeting the recommendations of mathematics teaching reform. Although, Cohen sees Oublier's growth as small, Oublier sees herself as making monumental changes given the demands of everyday teaching. In the present study, both participants reported that the professional development improved their teaching practices, and that the tasks they posed and the manner in which they questioned their students was consistent with the professional development pedagogies. Independent analysis of their classroom practices suggested otherwise. In the current study, the TIM-Teacher lens may not have been sufficiently sensitive to detect changes made in instructional practices. Future research is needed to compare teachers' with researchers' expectations of changes associated with professional development. Similar to the case of Mrs. Oublier, relatively modest shifts in instructional practices from a researcher's perspective may be important and valued from a teacher's perspective; conversely, the changes valued by teachers may be perceived as too incremental to impact student learning among researchers and policymakers.

Establishing baseline practices prior to professional development. This study examined how the professional development program influenced teacher-participants' enacted practices and how those enacted practices compared to participants' espoused practices, their intended practices and the professional development instructional practices. While the design of the current study provides information about how the professional development has influenced participants' enacted practices, it did not account for teachers' practices prior to the professional development. Future research is needed to provide researchers baseline data related to participants practices related to the LCPD in order to examine changes in classroom practice associated with the onset of professional development.

Limitations of the study

Participant recruitment. While a total of 24 teachers participated in the professional development project, only two agreed to participate in the study. Initially, I planned to purposefully sample four teachers representing a range of knowledge and skills related to implementing learner-centered tasks, integrating technology into their schools, and motivation for participating. Since my goal was to examine whether enacted practices were consistent with intended practices and the professional development pedagogies, I purposefully selected teachers who reported an interest and a desire to frequently enact the professional development practices.

In addition, I encountered barriers while recruiting participants. Due to limited interest in implementing learner-centered practices, participating in the research study, competing professional development projects, and concerns over being observed, relatively few teachers volunteered to participate. A third teacher initially agreed to participate but withdrew after the first observation due to classroom management concerns. Thus, while the analysis provided useful and detailed case evidence as to the links between professional development, classroom practice, and student learning for two participants, the initial targets for both number of participants and variation were not available.

This study might have been improved by increasing the number of participants. Approaches such as visiting the classrooms of the professional development participants and being more persistent in soliciting participation might have increased the number of volunteers. Further, my purposeful sampling criteria could have been modified, such as including teachers who attended the initial workshops and reported using technology in years past regardless of their reported interest in the workshop. While I suspected that reluctance to participate would influence their implementation, this might have proven an important dimension in examining differences in classroom practice.

Type of participants studied. Participants were chosen because they expressed enthusiasm for learner-centered professional development and reported an interest in using the practices in their classroom. Kubitskey et al. (2004) reported that most professional development researchers focus on volunteers who have an interest in participating, rather than “typical” participants. Thus, “optimal” participants who reported an advanced willingness to implement professional development practices might rate efforts more favorably and be more likely to implement than typical participants. In the present study, even motivated, optimal participants reported mixed reactions and demonstrated little application of the learner-centered practices in their classrooms. It is conceivable that even less support for and adoption of learner-centered pedagogies might be expected for teachers less willing to participate.

Using raters to analyze video data. The initial research plan called for expert raters to view and code video using the Video Analysis Tool (VAT) and the TIM-Teacher Lens. During rater training, the inter-rater reliability was high; I was confident that the raters would be able to use the VAT to accurately code the videos. However, implementation problems occurred during the study. During reliability testing, raters coded 5-minute segments rather than entire 45 to 60-minute classroom lesson sessions. After inter-rater reliability testing, each video was segmented into smaller clips that represented interactions between teacher and student; however, the raters were unable to access these smaller clips. A few attempted to analyze the segmented clips, but it proved difficult for raters to complete the task as required. In response, I coded each video twice. To minimize the possibility of simply duplicating the initial code, the second analysis was conducted a minimum of one week after the first. If discrepancies between codes were found, I viewed the video a third time to determine which, if either, was appropriate. In retrospect, upon learning that raters could not access the smaller clips, greater support was needed to ensure that the video evidence was more complete and usable and that my analysis could be compared with multiple raters.

Use of self-reported data. This study used interview data to examine teacher-participants' intended and espoused practices. Researchers have consistently documented a lack of reliability of teacher self-reported data (e.g., Buck Institute for Education, 2002; Mullens, 1998; Ravitz, 2003). In order to account for questionable reliability associated with self-reported data, participants intended and espoused practices were compared to their enacted practices, which were identified by analyzing *in situ* data in the form of video and field notes. While participants could have exaggerated reports of their espoused and intended practices, multiple observations and interviews as well as independent classroom observations were employed to triangulate data sources and minimize the potential limitations of self-report data.

Conclusion

This study provides evidence that scaffolding teacher's implementations can increase the likelihood of implementing learner-centered tasks—especially after teachers gain familiarity through professional development workshops and have opportunities to practice the methods with their students. However, even highly scaffolded tasks were sometimes implemented didactically. These findings are consistent with previous research indicating that well-established prior beliefs and instructional practices are often difficult to change during even semester- or year-long professional development initiatives.

This line of research is not intended solely to assess whether teachers' practices are aligned with the TIM instructional practices. Rather, the goal of professional development research is to extend our understanding about the interactions between teachers' perceptions of the instructional practices emphasized during professional development, beliefs about teaching and learning and professional development, and classroom practices related to the professional development. Due to inconsistencies between teachers' self-report and their observed behaviors, in situ observations are needed to sufficiently examine participants' implementation of professional development practices. Further, professional development researchers must continue to examine the links between teacher learning, teachers' implementations of their new knowledge and skills, and student learning outcomes.

References

Alexander, P. A. & Murphy, P. K. (1998). The research base for APA's learner-centered psychological principles. In N. M. Lambert & B. L. McCombs (Eds.), *Issues in school reform: A sampler of psychological perspectives on learner-centered schools* (pp. 33-60). Washington, DC: American Psychological Association.

APA Work Group of the Board of Educational Affairs (1997). *Learner-centered psychological principles: A framework for school reform and redesign*. Washington, DC: Author.

Ball, D. L. & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning professional: Handbook of policy and practice* (pp. 3-32). San Francisco: Jossey-Bass.

Ball, D. L., Lubienski, S. T., & Mewborn, D. S. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed.) (433-456). Washington, DC: American Educational Research Association.

Banilower, E. R., Boyd, S. E., Pasley, J. D., & Weiss, I. R. (2005). *Lessons from a decade of mathematics and science reform: Capstone report for the local systemic change through teacher enhancement initiative*. Chapel Hill, NC: Horizon Research, Inc.

Battey, D. S. & Chan, A. (2006, April). *Using planned and emergent mathematical tasks to describe opportunities for classroom practice and student learning*. Paper presented at the 2006 Annual Meeting of the American Educational Research Association, San Francisco, CA.

Bay, J. M., Reys, B. J., & Reys, R. E. (1999). The top 10 elements that must be in place to implement standards-based mathematics curricula. *Phi Delta Kappan, 80*(7), 503-506.

Blumenfeld, P., Fishman, B., Krajcik, J., Marx, R. W & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling-up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149-164.

Bogden, R. R. & Biklen, S. K. (2003). *Qualitative research in education: An introduction to theories and methods (4th. ed.).* Boston: Allyn & Bacon.

Borko, H., & Putnam, R. T. (1995). Expanding a teacher's knowledge base: A cognitive psychological perspective on professional development. In T.R. Guskey and M. Huberman (Eds.), *Professional development in education: New paradigms and practices* (pp. 35-61). New York: Teachers College, Columbia University.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3-15.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 115-141). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bransford, J. D., Brown, A., & Cocking, R. (Eds.). (2000). *How people learn: Mind, brain, experience and school, Expanded Edition.* Washington, DC: National Academy Press.

Buck Institute for Education (2002). *Teaching with technology: A Statewide professional development program*. Retrieved November 12, 2005, from http://www.bie.org/files/twtfinal.pdf

Carpenter, T., Fennema, E., & Franke, M. L. (1996). Cognitively guided instruction: A knowledge base for reform in primary mathematics instruction*.* *The Elementary School Journal*, *97*(1), 3-20.

CEO Forum on Education and Technology (2001). *The CEO Forum school technology and readiness report: Key building blocks for student achievement in the 21st century.* Retrieved February 21, 2002, from http://www.ceoforum.org/downloads/report4.pdf.

Coffey, A. & Atkinson, P. (1996). *Making sense of qualitative data: Complementary research strategies.* Thousand Oaks, CA: Sage.

Cognition and Technology Group at Vanderbilt (1992). The Jasper series as an example of anchored instruction: Theory, program description, and assessment data. *Educational Psychologist*, *27*(3), 291-315.

Cognition and Technology Group at Vanderbilt (1997). The Jasper Project: Lessons in curriculum, instruction, assessment, and professional development. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Cohen, D. K. & Ball, D. L. (1999). *Instruction, capacity, and improvement*. (CPRE Research Report No. RR—043). Philadelphia: University of Pennsylvania, Consortium for Policy Research in Education.

Cohen, S. (2005). *Teachers' professional development and the elementary mathematics classroom: Bringing understandings to light*. Mahwaw, NJ: Lawrence Earlbaum Associates, Inc.

Cooney, T. .J. 1985. A beginning teacher's view of problem solving. *Journal for Research in Mathematics Education 16*(5), 324-336.

Culp, K. M., Honey, M., & Mandinach, E. (2003). *A retrospective on twenty years of education technology policy*. Washington, DC: U.S. Department of Education, Office of Educational Technology. Retrieved August 2, 2005, from http://www.nationaledtechplan.org/participate/20years.pdf

Darling-Hammond, L. (1998). Teacher learning that supports student learning. *Educational Leadership, 55*(5), 6-11.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5-8.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*(3), 81-112.

Doyle, W. (1983). Academic work. *Review of Educational Research, 53*(2), 159-199.

Doyle, W. (1988). Work in mathematics classes: The context of students' thinking during instruction. *Educational Psychologist, 23*(2), 167-180.

Doyle, W., & Sanford, J. P., French, B. S., Emmer, E. T., & Clements, B. S. (1985). *Patterns of academic work in junior high science, English and mathematics classes: A final report* (R&D Rep. No 6190). Austin: University of Texas, Research and Development Center for Teacher Education.

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*(4), 47-61.

Fennema, L., Carpenter, T., Franke, M., Levi, M., Jacobs, V., & Empson, S. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education, 27*(4), 403-434.

Fernandez, C. (2003). Learning from Japanese approaches to professional development: The case of lesson study. *Journal of Teacher Education, 53(*5*),* 393-405.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teachers and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643-658.

Fogleman, J., & McNeil, K. L. (2005, April). *Comparing teachers' adaptations of an inquiry-oriented curriculum unit with student learning*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal.

Franke, M. L., Carpenter, T. P., Levi, L., & Fennema, E. (2001). Capturing teachers' generative change: A follow-up study of professional development in mathematics. *American Educational Research Journal, 38*(3), 653-689.

Fullan, M. G. (1995). The limits and the potential of professional development. In T.G. Guskey & M. Huberman (Eds.), *Professional development in education*: *New paradigms and practices.* Teacher's College Press: New York.

Fullan, M. G. (1991). *The new meaning of educational change* (2nd ed.). New York: Teachers College Press.

Garet, M., Porter, A., Desimone, L., Briman, B., & Yoon, K. (2001). What makes professional development effective? Analysis of a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

Georgia Department of Education (GADOE) (2005). *Georgia mathematics performance standards*. Retrieved January 7, 2005, from http://www.georgiastandards.org/ math.asp.

Georgia House of Representatives (2000). *A-plus education reform act of 2000*, House Bill 1187.

Glazer, E. M., & Hannafin, M. J. (2006). The collaborative apprenticeship model: Situated professional development within school settings. *Teaching and Teacher Education, 22*(2), 179-193.

Glazer, E. M., & Hannafin, M. J. (submitted). Using collaborative apprenticeship to examine factors and reciprocal interactions that affect a community of teachers' integration of technology. Submitted for publication.

Greeno, J. G. (1983, April). *Skills for representing problems*. Paper presented at the annual meeting of the American Educational Research Association, Montreal.

Guskey, T. R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan*, *84*(10), 748-750.

Guskey, T. R. (2005). Taking a second look at accountability. *Journal of Staff Development*, *26*(1), 10-18.

Hannafin, M. J. (1992). Emerging technologies, ISD, and learning environments: Critical perspectives. *Educational Technology Research and Development, 40(*1*)*, 49-63.

Hargreaves, A. (1997). Cultures of thinking and educational change. In B. J. Biddle (Ed.), *International handbook of teachers and teaching, Volume II,* (pp. 1297-1319). Boston: Kluwer Academic.

Hawley, W. D. & Valli, L. (1999). The Essentials of Effective Professional Development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice*, San Francisco: Jossey-Bass.

Hawley, W. D. & Valli, L. (2000). Learner-centered professional development. *Research Bulletin,* August 2000, No. 27. Phi Delta Kappa Center for Evaluation, Development, and Research. Retrieved February 22, 2005, from http://www.pdkintl.org/edres/resbul27.htm

Henningsen, M., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education, 28*(5), 524-549.

Hiebert, J., & Wearne, D. (1993). Instructional tasks, classroom discourse, and students' learning in second grade arithmetic. *American Educational Research Journal, 30*(2), 393–425.

Hill, H., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal, 42*(2), 371-406.

Hufferd-Ackles, K., Fuson, K. C, & Sherin, M. G. (2004). Describing levels and components of a math-talk learning community. *Journal for Research in Mathematics Education*, *35*(2), 81-116.

International Society for Technology in Education (2000). *National Educational Technology Standards for Students (NETS-S).* Author: Eugene, OR.

Jonassen, D. H. & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonassen, (Ed.), *Handbook of research on educational communications and technology* (pp. 693-719). New York: Macmillan.

Kennedy, M. (1998). *Form and substance in inservice teacher education* (Research Monograph No. 13). Madison: University of Wisconsin–Madison, National Institute for Science Education. Retrieved January 12, 2005, from www.wcer.wisc.edu/archive/nise/Publications/Research_Monographs/vol13.pdf

Kim, G., & Stein, M. K. (2006, April). *Analysis of the teacher learning demands of Everyday Mathematics and Investigations*. Presented at the 2006 Annual Meeting of the American Educational Research Association. San Francisco, CA.

Knezek, G. & Christensen, R. (2004, March). *Impact of technology-intensive professional development on classroom gains in reading achievement*. Paper presented at the 2004 Society for Information Technology and Teacher Education Annual Meeting, Atlanta, GA.

Kubitskey, B., Fishman, B. J., & Marx, R. (2003, April). *The relationship between professional development and student learning: Exploring the link through design research*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Kubitskey, B. & Fishman, B. J. (2005, April). *Untangling the relationship(s) between professional development, practice, student learning and teacher learning*. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

LeCompte, M. and Preissle, J. (1993). *Ethnography and qualitative design in educational research,* (2nd ed.). New York: Academic Press.

Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, *15*(2), 129-151.

Lortie, D.C. (1975). *Schoolteacher*. Chicago: University of Chicago Press.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science. The state of the scene. *School Science and Mathematics, 99*(5), 258-271.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S. & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics (2nd ed.)*. Thousand Oaks, CA: Corwin Press.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States.* Mahwah, NJ: Lawrence Erlbaum Associates.

Mann, D., Shakeshaft, C., Becker, J., & Kottkamp, R. (1999). *West Virginia's basic skills/computer education program: An analysis of student achievement*. Santa Monica, CA: Milken Family Foundation.

Marx, R. W., Blumenfeld, P. C., & Krajcik, J. S. (1998). New technologies for teacher professional development. *Teaching and Teacher Education 14*(1), 33-52.

Marzano, R., Pickering, D., & Pollock, J. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Alexandria, VA: ASCD.

McCombs, B. L., & Whisler, J. S. (1997). *The learner-centered classroom and school: Strategies for increasing student motivation and achievement*. San Francisco: Jossey-Bass.

McCombs, B. L. (2000, September). *Assessing the role of educational technology in the teaching and learning process: A learner-centered perspective*. Paper presented at the Secretary's Conference on Educational Technology: Measuring the Impacts and Shaping the Future, Washington, DC. Retrieved July 6, 2005, from http://www.ed.gov/rschstat/eval/tech/techconf00/mccombs_paper.html

McCombs, B. L. (2001). What do we know about learners and learning? The learner-centered framework: Bringing the educational system into balance. *Educational Horizons*, *79*(4), 182-193.

McCombs, B. L. (2003). A framework for the redesign of K-12 education in the context of current educational reform. *Theory into Practice, 42*(2), 163-167.

Means, B. (1994). Technology and education reform. San Francisco: Jossey-Bass.

Merriam, S. B. (2002). Qualitative research in practice: Examples for discussion and analysis. San Francisco, CA: Jossey-Bass.

Milken Family Foundation (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality*. Princeton, NJ: ETS. Retrieved January 12, 2005 from http://www.mff.org/pubs/ets_mff_study2000.pdf.

Mullens, J. (1998). *Validating teacher responses on instructional practice self-report surveys.* Prepared for the Association for Public Policy Analysis and Management Research Conference, New York. Retrieved January 12, 2005, from http://www.amstat.org/sections/SRMS/Proceedings/papers/1999_118.pdf

National Center for Educational Statistics (NCES) (2000). *Pursuing excellence: Comparisons of international eighth-grade mathematics and science achievement from a U.S. perspective, 1995 and 1999*. Retrieved January 12, 2005 from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2001028.

National Center for Educational Statistics (2004). *The nation's report card: Mathematics*. Retrieved January 12, 2005, from http://nces.ed.gov/nationsreportcard/.

National Council of Teachers of English (1996). *Standards for the English language arts*. Urbana, IL: Author.

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Partnership for Excellence and Accountability in Teaching (NPEAT) (2000a). *Improving professional development: Research based standards*. Washington, DC: Author.

National Partnership for Excellence and Accountability in Teaching (NPEAT) (2000b). *Revisioning professional development: What learner-centered professional development looks like*. Oxford, OH: Author. Retrieved September 10, 2003, from http://www.nsdc.org/library/policy/npeat213.pdf

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

National Staff Development Council (2001). NSDC Standards for Staff Development. Retrieved January 12, 2005 from http://www.nsdc.org/standards/index.cfm.

No Child Left Behind (NCLB) Act of 2001 (2002). Pub. L. No. 107-110, 115 Stat. 1425.

Orrill, C. H. (2001). Building learner-centered classrooms: A professional development framework for supporting critical thinking. *Educational Technology Research and Development*, *49*(1), 15-34.

Orrill, C. H., Calhoun, J. K., Sikes, C. K. (2002). *Learning in LTTS: Value, usability and professional growth*. Athens, GA: University of Georgia. Learning and Performance Support Laboratory.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful Ideas*. New York: Basic Books.

Patton, M.Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Peterson, P. L. (1990). Doing more of the same: Cathy Swift. *Educational Evaluation and Policy Analysis*, *12*(3), 261- 280.

Peterson, P.L., Putnam, R.T., Vredevoogd, J., & Reineke, J.W. (1992). Profiles of practice: Elementary school teachers' views of their mathematics teaching. In W.G. Secada (Ed.), *Special issue of the International Journal of Educational Research*: 17 (5), 471–488.

Pink, W.T. (1992). A school-within-a-school for at-risk youth: Staff development and program success. In W.T. Pink and A.A. Hyde (Eds.), *Effective Staff Development for School Change* (pp. 96-110). Norwood, NJ: Ablex.

Pink, W. T., & Hyde, A. A. (1992). Doing effective staff development. In W.T. Pink and A.A. Hyde (Eds.), *Effective Staff Development for School Change* (pp. 5-22). Norwood, NJ: Ablex.

Polly, D., Ledford, S. D., Orrill, C. H., & Bleich, L. (2005, April). *Learning technology in the context of professional development*. Presented at the 2005 Annual Meeting of the American Educational Research Association: Montreal.

Prawat, R. S. (1992). Are changes in views about mathematics teaching sufficient? The case of a fifth-grade teacher. *The Elementary School Journal*, *93*(2), 195-211.

Putnam, R., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teaching? *Educational Researcher, 29*(1), 4-15.

Ravitz, J. (2003). Balancing teachers' willingness to change with classroom realities: Moving towards an error-free model in professional development research. Retrieved November 11, 2005 from www.bie.org/files/RavitzSITE2003.pdf

Recesso, A., Hannafin, M. J., Wang, F., Deaton, B., Shepherd, C., & Rich, P. (in press). Direct evidence and the continuous evolution of teacher practice. In P. Adamy & N. Milman (Eds.), *Evaluating electronic portfolios in teacher education*. Greenwich, CT: Information Age Publishing, Inc.

Reeves, T. C., Herrington, J., & Oliver, R. (2005). Design research: A socially responsible approach to instructional technology research in higher education. *Journal of Computing in Higher Education 16*(2), 97-116.

Reeves, T. C., & Okey, J. (1996). Alternative assessment for constructivist learning environments. In B. Wilson (Ed.), *Constructivist learning environments* (pp. 191-202). Englewood Cliffs, NJ: Educational Technology.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Richardson, V. (1990). Significant and worthwhile change in teaching practice. *Educational Researcher, 19*, 10-18.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula & T. Buttery & E. Guyton (Eds.), *Handbook of Research on Teacher Education* (pp. 102-119). New York: Simon & Schuster Macmillan.

Ringstaff, C., & Kelley, L. (2002). *The learning return on our educational technology investment.* San Francisco: WestEd.

Ringstaff, C. & Yokam, K. (1994). *Creating an alternative context for teacher development: The ACOT teacher development centers*. Retrieved January 12, 2005, from http://images.apple.com/education/k12/leadership/acot/pdf/rpt17.pdf

Ringstaff, C., Yokam, K., & Marsh, J. (1995). *Integrating technology into classroom instruction: An assessment of the impact of the ACOT teacher development center project.* Report to Apple Computer. Retrieved August 3, 2004, from http://www.apple.com/education/k12/leadership/acot/library.html

Roblyer, M. D. & Knezek, G. C. (2004). New millennium research for educational technology: A call for a national research agenda. *Journal of Research on Technology in Education, 36*(1), 60-71.

Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2001). Changing how and what children learn in schools with computer-based technologies. *The Future of Children, 10*(2), 76-101.

Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*. NY: Teachers College Press.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. *American Psychology, 54*(3), 182-203.

Schacter, J. (1999). *The impact of education technology on student achievement: What the most current research has to say.* Santa Monica, CA: Milken Exchange on Education Technology.

Schifter, D., Bastable, V., Russell, S. J. (2002). *Developing mathematical ideas: Measuring space in one, two, and three dimensions*. Parsippany, NJ: Dale Seymour.

Schifter, D. & Fosnot, C. (1993). *Reconstructing mathematics education: Stories of teachers meeting the challenge of reform*. New York: Teachers College, Columbia University.

Schifter, D., & Simon, M. A. (1992). Assessing teachers' development of a constructivist view of mathematics learning. *Teaching and Teacher Education*, 8(2), 187-197.

Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Education*, *42*(3), 283-312.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York: Macmillan.

Schon, D. (1983). The reflective practitioner: *How professionals think in action*. New York: Basic Books, Inc.

Schrum, L. (1999). Technology professional development for teachers. *Educational Technology Research and Development*. *47*(4), 83-90.

Sherin, M. G., & van Es, E. A. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, *13*(3): 475-491.

Silver, E. A., Smith, M. S., & Nelson, B. S. (1995). The QUASAR Project: Equity concerns meet mathematics education reform in the middle school. In W. G. Secada, E. Fennema & L. B. Adajian (Eds.), *New directions for equity in mathematics education* (pp. 9-56). New York: Cambridge University Press.

Silver, E. A., & Stein, M. K. (1996). The QUASAR project: The "revolution of the possible" in mathematics instructional reform in urban middle schools. *Urban Education*, *30*(4), 476-521.

Simon, M. A., & Schifter, D. (1991). Towards a constructivist perspective: An intervention study of mathematics teacher development. *Educational Studies in Mathematics*, *22*(8), 309-331.

Song, L., Hannafin, M. J., & Hill, J. R. (in press). Reconciling beliefs and practices in teaching and learning. *Educational Technology Research and Development*.

Sparks, D. & Hirsch, S. (2000). *A national plan for improving professional development*. (ERIC Document ED 442 779).

Stein, M. K. & Brown, C. A. (1997). Teacher learning in a social context: Social interaction as a source of significant teacher change in mathematics. In E. Fennema & B. Nelson (Eds.), *Mathematics teachers in transition* (pp. 155-191). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Stein, M. K., Grover, B. W., and Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal*, *33,* 455–488.

Tarr, J. E., Chávez, Ó. Reys, R. E., Reys, B. J. (2006). From the written to the enacted curricula: the intermediary role of middle school mathematics teachers in shaping students' opportunity to learn. *School Science and Mathematics*, *106*(4), 191-201.

TERC (2004). *Investigations in number, data, and space*. White Plains, NY: Dale Seymour.

Tharp, R., & Gallimore, R. (1988). Rousing minds to life: Teaching, learning, and schooling in social context. New York: Cambridge University Press.

The Concord Consortium (n.d.). *Balanced assessment in mathematics*. Retrieved January 15, 2006 from http://balancedassessment.concord.org/aboutprogram.html

Thompson, A. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 127-146). New York: MacMillan.

University of Chicago School Mathematics Project (2004). *Everyday mathematics.* Chicago, IL: McGraw Hill.

U.S. Department of Education (1998). *Status of education reform in public elementary and secondary schools: Teachers' perspectives.* NCES Document No. 1999-045. Retrieved November 18, 2005, from http://nces.ed.gov/programs/quarterly/vol_1/1_1/4-esq11-g.asp

van Es, E. A. & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571-596.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development, 53* (4), 5-23.

Wenglinsky, H. (1998). Does it compute? The relationship between educational technology and student achievement in mathematics. *Educational Testing Service Policy Information Center*. Retrieved September 10, 2002, from www.mff.org/pubs/ME161.pdf.

Wilson, S. M. (1990). A conflict of interests: The case of Mark Black. *Educational Evaluation and Policy Analysis, 12*(3), 309-326.

Wilson, S.M. & Berne, J. (1999). *Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional* *development*. In A. Iran-Nejad & C.D. Person (Eds.). *Review of Research in Education*, (pp. 173-209). Washington, D.C.: American Educational Research Association.

Yocam, K. & Wilmore, F. (1994). Creating an alternative context for teacher development: ACOT's two-year pilot project. Retrieved January 12, 2005 from http://images.apple.com/education/k12/leadership/acot/pdf/rpt17.pdf

Appendix A: Participant Information Sheet

TIM Participant Information Sheet
Created by Dr. Chandra Hawley Orrill

Name: _______________________________

E-mail address: ________________________

Where do you teach? ________________________ Grade level: ____________

Have you used technology to teach math to your students in the past? (If so, what kinds of things have you done?

What do you hope to learn this year as a TIM participant?

Why did you choose to participate in TIM?

Appendix B: TIM-Teacher Lens

Practice	**The teacher…**
Use of Algorithms	0- does not provide an algorithm or provide activities where students generalize or develop an algorithm 1- provides an algorithm for students to use without discussing why the algorithm works 2- provides an algorithm for students to use with the opportunity to see why it works 3- provides mathematical tasks in which students explore the tasks and students identify an algorithm
Mathematical Tasks	0- does not provide opportunities for students to work on mathematical tasks 1- provides opportunities for students to work on tasks that do not use resources (e.g. manipulatives or technology) and involve completing a procedure given by the teacher 2- provides opportunities for students to work on tasks in which students use appropriate resources and follow a procedure given by the teacher 3- provides opportunities for students to work on tasks in which students use appropriate materials, choose their own approach and provide a solution
Students' mathematical communication	0- does not provide opportunities for students to communicate their mathematical thinking 1- provides opportunities for students to provide an answer to the teacher or classmates 2- provides opportunities for students to share answers and their mathematical thinking with the teacher 3- provides opportunities for students to communicate their mathematical thinking with one another and facilitates student-to-student communication
Representations of Mathematical Concepts	0- does not provide representations of mathematical concepts 1- provides teacher-generated representations of mathematical concepts which the student uses to solve an investigation 2- provides opportunities for students to generate their own representation of mathematical concepts 3- provides opportunities for students to generate multiple representations of mathematical concepts

Integration of Technology	0- does not use technology in their mathematics classroom 1- uses technology to tell information to their students (PowerPoint, projector) 2- provides opportunities for students to use technology as an activity in mathematics that is used to enhance students' computational skills 3- provides opportunities for students to engage in an activity where the teacher uses technology and the activity involves solving problems and tasks with the assistance of the technology (e.g.: teacher modeling how to use a spreadsheet to graph data, using virtual manipulatives) 4- provides opportunities for students to use technology to develop their mathematical knowledge and/or problem solving skills
Asking Questions that Elicit Student Thinking	0- does not ask questions 1- asks questions that elicit only a mathematical answer or definition 2- asks questions and follow-up questions that probe more deeply at students' mathematical ideas and thinking 3- facilitates by asking questions and encouraging students to ask questions about other students' mathematical thinking

Appendix C: Baseline Interview Protocol

Purpose of question	**Interview Question**	**Possible Follow-Up Questions**
Background about teaching	Please tell me about your teaching background.	How long have you taught? What grade levels have you taught?
Background about mathematics teaching	Please tell me about your mathematics classroom.	What is your role in this classroom? What are the students doing?
Espoused views about technology's role in mathematics	Please talk about the use of technology in your mathematics classroom.	How do you use technology? How do students use technology? How does it help?
Espoused views about mathematics teaching	Please talk about how you think students' best learn mathematics.	What is your typical role as a mathematics teacher? What are the students typically doing? What resources or materials are needed? How do you know that learning is taking place?
Espoused and intended practices	Please tell me how you think this project has influenced your teaching.	What practices have you already used in your classroom? What practices do you plan on using?

Appendix D: Post-observation Interview Protocol

Purpose of question	Interview Question	Possible Follow-Up Questions
Intended practices	Please tell me about what you were planning on doing during today's lesson.	What were the goals of the lesson? What were your expectations prior to starting? What strategies did you plan on using to help the students learn?
Challenges of the observed lesson	Please talk about challenges that you observed.	What caused the challenges? How did you attempt to overcome them? What would you do differently next time?
Success of the observed lesson	Please talk about the successes that occurred during the lessons.	What factors led to these successes?
Espoused practices	Please talk about how the practices emphasized in this project influenced your teaching during these two lessons.	How effective were those practices? How did your students react to those practices?
Espoused practices	How did this lesson compare to how you taught this content last year?	What new practices have you used? What changes will you make for future lessons?

Appendix E: End-of-Study Interview Protocol

Purpose of question	**Interview Question**	**Possible Follow-Up Questions**
Overview of TIM Project	Please talk about your experience in this project.	How has this project influenced your knowledge of mathematics? What activities have had the largest impact on your math knowledge? How has this project influenced your technology skills? What activities have had the largest impact on your technology skills?
Espoused Practices about mathematics teaching	Please talk about how this project has influenced your mathematics teaching.	What is different in your math classroom now compared to a year ago? Activities? Your role in the classroom Checking for student understanding Questioning students
Espoused practices about technology	Please talk about how your use of technology in your math teaching compares to a year ago?	Do you use it differently? Do students use it differently?
Intended Practices	How satisfied are you with your mathematics teaching this year?	What is your role? What are the students doing? What would you like to do differently?
Ideal Mathematics Classroom	How do you think students best learn mathematics?	What role does the teacher have? What are the students doing? What resources or materials are needed? How do you know that learning is taking place? Does assessment have a role in your ideal classroom? What is it? How does it look?

Appendix F: Project Staff Interview Protocol

Purpose of question	**Interview Question**	**Possible Follow-Up Questions**
Teachers’ learning during TIM	Please talk about the goals of this project.	What do you think the teachers thing the goals are? What leads you to think that they have learned these things? What barriers have hindered their learning?
Overview of TIM workshops	Please tell me about the workshops.	What activities took place? How did these activities support teachers’ learning of technology? Math content? What was your role during the workshops? What were the teachers’ reactions?
Intended and Enacted Practices	Please talk about specific practices that you intend teachers to use in their mathematics classroom.	How well will teachers be able to enact these practices? What support do teachers need in order to effectively implement these practices in their classroom?
Participants’ View of Mathematics	Are the teachers where you expected them to be in terms of their mathematics content knowledge?	What do you think is their idea of good mathematics teaching? How does their idea of good teaching compare to yours?
Participants’ Technological Skills	Are the teachers where you expected them to be in terms of their technology skills?	What were some of the technologies that they saw during workshops? How do you think they see technology being used in the classroom? What evidence do you have this? How did they develop throughout the project?

Appendix G: Spreadsheet used to organize and analyze the video data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	File Name	Class	Plan	Start Time	End Time	Alg	Tasks	Comm	Reps	Tech	Ques	Comments			
2	dpolly_24	5th-EIP	3	3:36	4:00		2.3	3.3	4.3	5.3	6.3	base-10 blocks to help addition and subtractic			
3	dpolly_24	5th-EIP	3	4:00	4:14		2.3	3.2	4.3	5.3	6.2	T, "is this the tenths place? What place value			
4	dpolly_24	5th-EIP	3	4:15	5:09			3.2			6.2	T, "what are you doing w/ your units?" T, "and			
5	dpolly_24	5th-EIP	3	5:11	5:29			3.3			6.3	T, "I see a blue number up here. What does t			
6	dpolly_24	5th-EIP	3	5:27	7:39			3.2			6.2	T, "how many of these [points to rods] do you			
7	dpolly_24	5th-EIP	3	7:55	9:06		2.3	3.2	4.3	5.3	6.2	T, "you"re trying to subtract 8 from 3 is that pc			
8	dpolly_24	5th-EIP	3	9:13	9:30		2.3	3.2	4.3	5.3	6.2	T asks S to read number 0.428 and 0.885. T			
9	dpolly_24	5th-EIP	3	9:34	10:07			3.2			6.2	T, "you started doing your subtract when you			
10	dpolly_24	5th-EIP	3	10:06	10:48		2.3	3.3	4.3	5.3	6.3	T, "why did you have to borrow?" S, "cuz 9 car			
11	dpolly_24	5th-EIP	3	10:46	11:02			3.2			6.2	T, "what place value are you working in right r			
12	dpolly_24	5th-EIP	3	11:15	12:11			3.2			6.2	T, "I see you were going to go borrow from th			

Appendix H: Spreadsheet used to analyze participants' enacted practices.

5th	dpolly_1	0.1	0.2	0.3	0.4	0.5		dpolly_1	0.1	0.2	0.3	0.4
EIP	Algorithms	0	8	0	0	na	8	Algorithms	0.00%	100.00%	0.00%	0.00%
30-Sep	Tasks	4	5	1	0	na	10	Tasks	40.00%	50.00%	10.00%	0.00%
division	Comm	7	26	2	0	na	35	Comm	20.00%	74.29%	5.71%	0.00%
	Reps	0	1	2	0	na	3	Reps	0.00%	33.33%	66.67%	0.00%
	Tech	0	1	0	1	0	2	Tech	0.00%	50.00%	0.00%	50.00%
	Questions	9	23	2	0	na	34	Questions	26.47%	67.65%	5.88%	0.00%

Appendix I: Spreadsheet used to analyze interview data

Teacher	Code	Subcode	Sub (2)	Excerpt	Line number	File
Shantel	espousded practices	communicaton	EIP	R: So do you think they're becoming more open sharing their response when I'm here and when I'm not here or just when the camera is in the room. I: They are like that whether the camera is on or not where before they were what I would call inactive learners they were waiting for me to give it to them now they're coming out and getting it they are active in their learning and they are learning I mean they are understanding it a lot better because they are active and doing participating they're raising their hands more before I would have to call on students who didn't have their hands up and were they weren't going to raise their hands but they were talking you know even when they weren't called on so they're participating	104-113	jr-int-1
Shantel	espousded practices	communicaton	EIP	increase throughout the year? I: And they are more comfortable with math also more comfortable with what their findings were even they knew that there's were different they would you know raise their hands and say "well I didn't get that I got" and I like that you know and I always tell them "be able to back it up if you can tell me you have an answer show me how you got it and prove to me that your answer is correct" and they were comfortable with doing that	114-120	jr-int-1

Appendix J: Codes used to analyze interview data

Code	Description
Beliefs about learning	Participant shares their beliefs about how students learn.
Beliefs about learning mathematics	Participant shares their beliefs about how students learn mathematics
Beliefs about students	Participant shares beliefs about students in their mathematics classroom(s).
Beliefs about teaching	Participant shares beliefs about teaching mathematics.
Beliefs about technology	Participant shares beliefs about using technology in their mathematics classroom.
Collaboration	Participant shares experiences collaborating with a teacher or a professional developer.
Teacher-to-student communication	Participant discusses instances of communication between themselves and a student.
Co-planning	Participant discusses co-planning a lesson with a professional developer.
Education	Participant shares information about their education.
EIP to AGL classes	Shantel discusses similarities and differences between her EIP classes and her at grade level (AGL) classes
Espoused practices	Participant discusses instructional practices that they incorporated into their lesson.
Evidence about student learning	Participant discusses how she determined whether or not students learned during the lesson.
Intended goals	Participant shares the intended goals for the lesson.
Intended practice	Participant shares the instructional practices that she intended to use during the lesson.
Math knowledge	Participant discusses her knowledge of mathematics concepts that she taught.
Model teaching	Participant discusses watching a professional developer teach a lesson to her students.
Observations	Participant discusses observations of students that they made while teaching.
Professional development	Participant discusses the professional development experience in general.
Professional development activities	Participant discusses the activities that they completed during the professional development.
PD on teaching	Participant discusses how they think the professional development has influenced their teaching.
Perception of barriers	Participant discusses perceived barriers that prevent them from teaching in the manner that is suggested during the professional development.
Resources for lesson planning	Participant discusses resources they used to plan the lesson.

Reasons for participating	Participant discusses why they decided to participate in the professional development.
Mathematical representations	Participant discusses mathematical representations used during the lesson.
Resources	Participant discusses manipulatives and technology used during the lesson.
Student struggles	Participant discusses struggles that their students had during the lesson.
Tasks	Participant discusses tasks enacted during the lesson.
Teacher's role	Participant discusses teacher's role during the implementation.
TIM vs. typical	Participant discusses lessons that are aligned with the professional development compared with lessons that they have taught that were not aligned with the professional development.
VAT	Participant discusses the Video Analysis Tool (VAT).

Appendix K: Spreadsheet used for the analysis of Question Two

Tasks	Class	Plan	Summary of Intended	Summary of Enacted	Espoused Data
29-Sep	AGL	1	division tasks in the context of real-world scenarios, level-2; goal is recognize "equal sharing"	dilluted tasks, decontextualized after students started struggling, difficulties working w/ base-10 blocks, level-2	I: What were some signs that some of them just weren't getting it? J: O.K. Well as far as looking at the base-10 blocks one of the things the problem all they had to do was take 19 of something and divide it by 3 they were still multiplying they you know I: So they had 3 rows of 19 each, like 3 times 19? J: Yes. And I wanted to I would want to ask them why did we do that and why didn't that work and the kids
30-Sep	EIP	1	division tasks in the context of real-world scenarios, level-2; more modeling of tasks as a result of 9/29 enactment; goal is recognize "equal sharing"	dilluted tasks, decontextualized, difficulties w/ fundamental division, level 2 despite intent	Were there common mistakes? J: Yes for some because they are not what is it for their facts their multiplication facts they're not that good at them because they don't practice enough they you know the numbers were wrong like they would have 7 times 5 but they would say that 7 times 5 is 30 or things like that it would just be multiplication errors. I: So they would get wrong the minor computations within the larger problem?
			purpose is to		I: You mentioned earlier that w/ your class you had to make that

Appendix L: Spreadsheet for the Analysis of Question Three

Class	Date	Planning	Task level	math work	Mathematical representations	technology	Task Description
4th	19-Jan	DA	3	none	SG		S select their own tangram puzzle and us
4th	16-Feb	IN-NC	3	answers, computation	SG	t	S use calculators and choose their apprac
4th	16-Mar	CO-C	3	answers, computation	SG		S use tiles and choose their approach to c
4th	14-Oct	IN-C	1	answers	N		round-the-world
4th	14-Oct	IN-C	2	arrays	SG		S make multiplication arrays on typing pap
4th	21-Oct	IN-C	1	answers	TG		partial product
4th	18-Nov	CO-C	1	answers	N	t	Brainchild problems
4th	18-Nov	CO-C	1	answers	N		dice game
4th	18-Nov	CO-C	1	no	N		board game
4th	18-Nov	CO-C	1	no	N		flash cards
4th	18-Nov	CO-C	2		CG	t	factor game
4th	19-Dec	IN-C	2		SG	t	S use website to make bargraphs, scriptec

Appendix M: Description of Participants' Enactments (page 1 of 3)

	Date	Lesson Topic	Class	*Description of enacted task types*
Direct Adoption	9/29	Division with base-10 blocks	Shantel-AGL	Shantel assigns division tasks. Students use base-10 blocks to represent the division problem and solve the task. Students also solve the task using the traditional division algorithm.
	9/30		Shantel-EIP	Shantel assigns division tasks. Students use base-10 blocks to represent the division problem and solve the task. Students also solve the tasks using the traditional division algorithm. At the end of the lesson, students are introduced to an alternative algorithm and solve three tasks using an alternative algorithm.
	1/19	Tangram Puzzles	Keisha	Students are given a worksheet with tangram puzzles on it and two sets of tangrams. Students select a tangram puzzle and attempt to use the pieces to make the puzzle.
Co-planned lessons related to professional development content	11/18	Various multiplication tasks	Keisha	Students play the Factor Game (http://illuminations.nctm.org/Activity Detail.aspx?ID=12) with an assigned partner.
				Students play a board game in groups of 3-4 students. Students answer questions about their multiplication basic facts and move their game piece when they answer correctly.
				Students work with a partner to review flash cards about basic multiplication facts.
				Students use the BrainChild personal learning system to independently complete multiplication computations and one-step word problems. Students are given four multiple choice options for each problem and receive immediate feedback on whether they are correct.
				In a group of four, students roll two dice and generate a two-digit by a one-digit multiplication problem. Students independently use the traditional algorithm to complete the tasks. One student in each group does not work on the tasks; instead, they use the calculator to get the answer and provide feedback to the other students.
	3/16	Area and perimeter of rectangle	Keisha	In groups of four, students are given plastic square tiles and four rectangular objects around the classroom. Students are told to measure the area and perimeter of all four objects.

Appendix M: Description of Participants' Enactments (page 2 of 3)

	Date	**Lesson Topic**	**Class**	*Description of enacted tasks*
Co-planned lessons not related to professional development content	3/17	Equivalent decimals, adding and subtracting decimals	Shantel-EIP	Shantel reads decimals orally to students who represent the decimal with base-10 blocks on a place value mat and write the decimal in numeric form. Towards the end of the lesson, students only write the numeric form of the decimal.
			Shantel-AGL	Shantel reads decimals orally to students who write the numeric form on a miniature whiteboard.
				In the school's computer lab half of the students work on skills-based decimal tasks (http://www.aaaknow.com/dec.htm)
				In the school's computer lab half of the students work on web-based addition and subtraction tasks (http://nlvm.usu.edu/en/nav/category_ g_2_t_1. html) that are represented in both written form and with virtual base-10 blocks.
	3/22	Adding and subtracting decimals	Shantel-EIP	In the school's computer lab students work on web-based addition and subtraction tasks that are represented in both written form and with virtual base-10 blocks.
Independently planned lessons related to the professional development content	10/4	Array models of multiplication	Keisha	Students draw array models of multiplication on construction paper and cut them out.
	10/12	Partial product algorithm for multiplication	Keisha	Students are introduced to the partial product multiplication algorithm. Students then use the algorithm to complete tasks.
	12/14	Identifying triangles by side length	Shantel-EIP	Students create a triangle on a geoboard that resembles one that Shantel has shown on the overhead projector. Students use rulers and are told to classify the triangle based on the side lengths.
	1/19	Estimating linear units	Shantel-EIP	Students are given measuring tools that are 1 centimeter, 1 decimeter and 1 meter long. Students examine objects in the classroom and have to locate 15 objects; five each that could appropriately be measured in centimeters, decimeters and meters.
			Shantel-AGL	Students are given measuring tools that are 1 centimeter, 1 decimeter and 1 meter long. Students examine objects in the classroom and have to locate 15 objects; five each that could appropriately be measured in centimeters, decimeters and meters.
	3/16	Multiplication and division puzzles	Keisha	Students are given a worksheet with multiplication and division puzzles and a calculator. Students work with assigned partners to complete the puzzles.

Appendix M: Description of Participants' Enactments (page 3 of 3)

	Date	Lesson Topic	Class	*Description of enacted tasks*
Independently planned lessons not related to professional development content	10/28	Identifying the LCM	Shantel-AGL	Shantel reads numbers to students who identify both the common multiples and the least common multiple for the numbers.
			Shantel-EIP	Shantel types numbers into a computer that is shown using an LCD projector. The students read the common multiples and the least common multiple off of the computer screen.
	11/9	Identifying prime and composite numbers	Shantel-EIP	Students make arrays using a specific number of tiles. Students examine the number of arrays that was made to determine if a number is prime or composite.
			Shantel-AGL	Students make arrays using a specific number of tiles. Students examine the number of arrays that was made to determine if a number is prime or composite.
	11/18	Various decimals tasks	Shantel-EIP	Shantel types in two decimals into a computer that is shown using an LCD projector. Students add up the two decimals on paper.
				Students read a decimal off of a worksheet and represent it using base-10 blocks.
				Students use the Brainchild to complete tasks related to adding, subtracting and multiplying decimals.
				Students use the Playstation to complete tasks related to decimals, percents and fractions.
			Shantel-AGL	Shantel types in two decimals into a computer that is shown using an LCD projector. Students add up the two decimals on paper.
				Students read a decimal off of a worksheet and represent it using base-10 blocks.
				Students use the Brainchild to complete tasks related to adding, subtracting and multiplying decimals.
				Students use the Playstation to complete tasks related to decimals, percents and fractions.
				Students use a grocery store flyer to identify prices of foods. On paper, they add up the prices of foods that they select.
	12/19	Bar Graphs	Keisha	In the school's computer lab, students work with an assigned partner to use a web-based tool to create bar graphs for survey data that they had collected a week earlier.
	2/16	Arithmetic Mean	Shantel-EIP	Students use a calculator to find the mean for sets of numbers. After doing two tasks, students use paper and pencil to find the mean for the remaining tasks.