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 4th 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 4th 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.

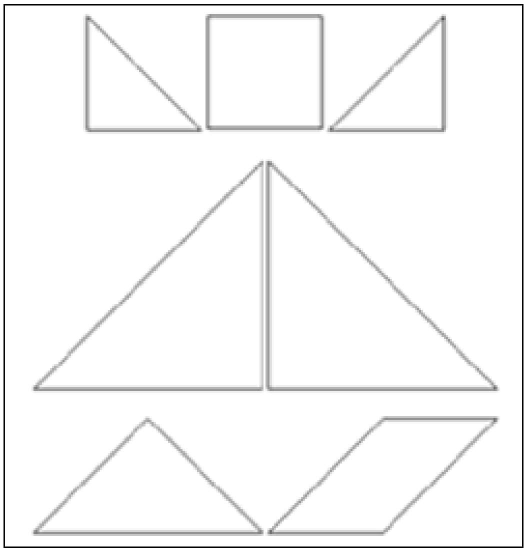

Figure 4.3: A set of tangram pieces.

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).

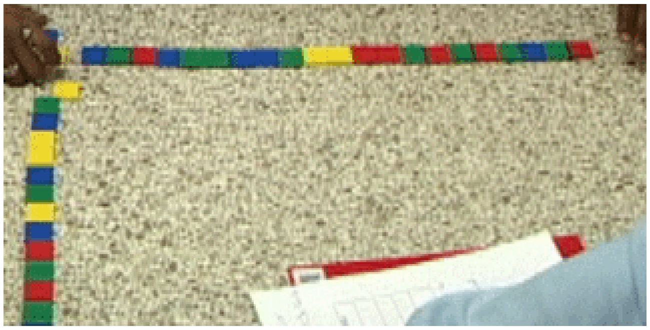

Figure 4.4: Students determine the area and perimeter of a hallway tile.

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.

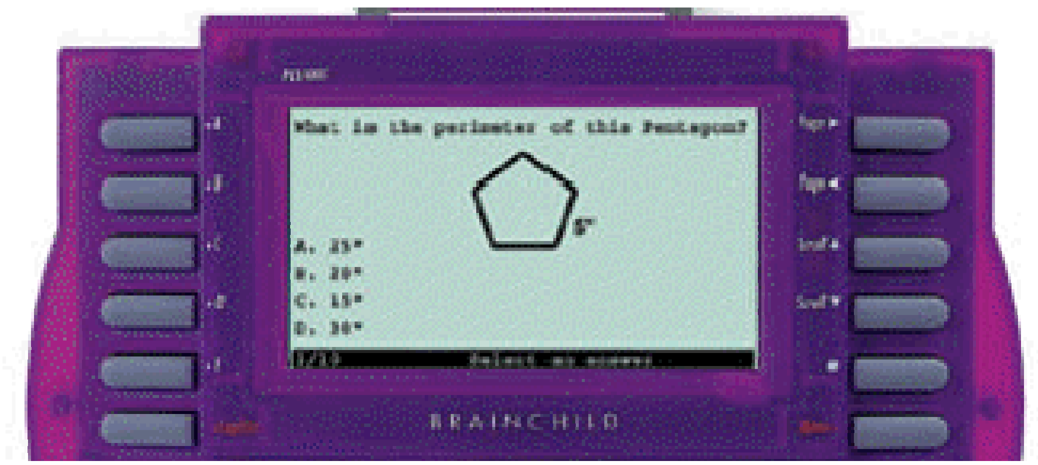

Figure 4.5: The Brainchild computer system.

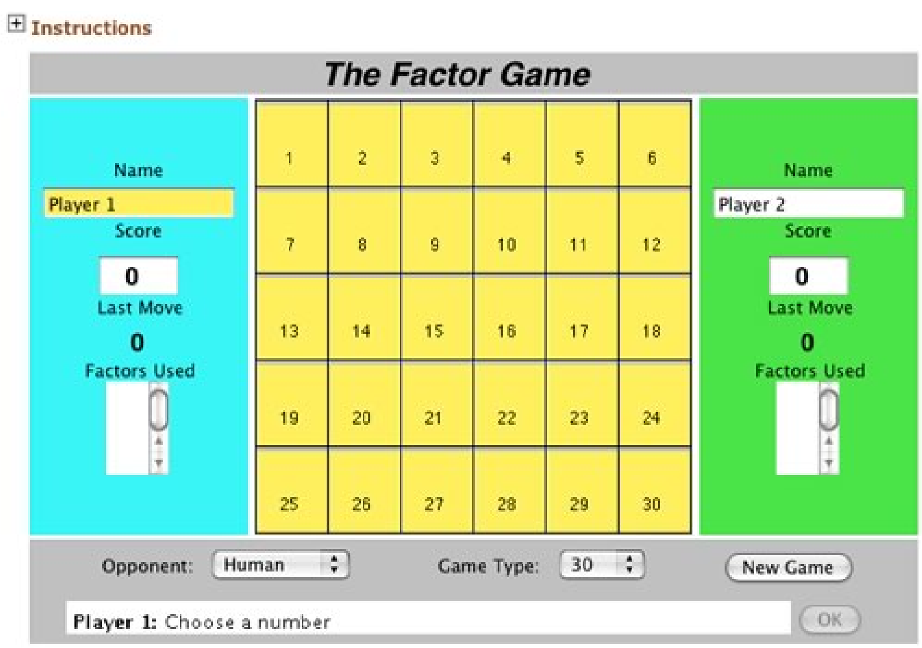

Figure 4.6: Screen capture of the Factor Game.

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.

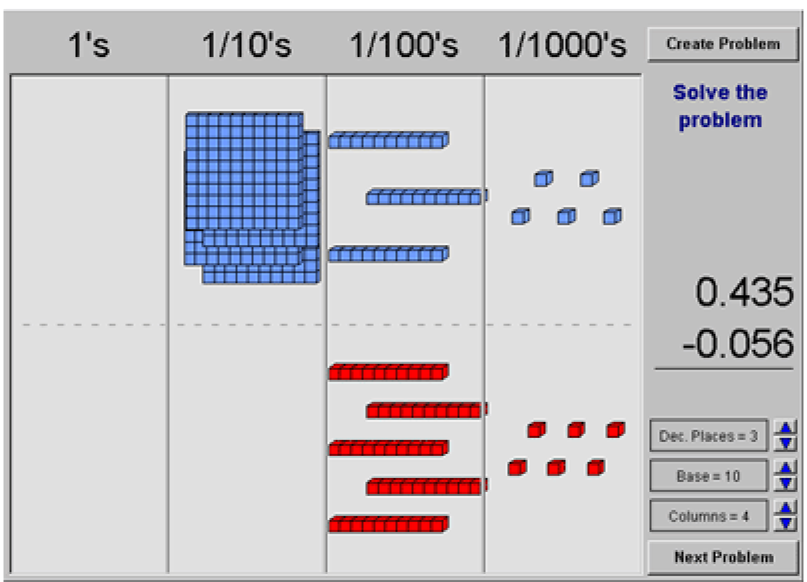

Figure 4.8: Subtraction of decimals tasks.

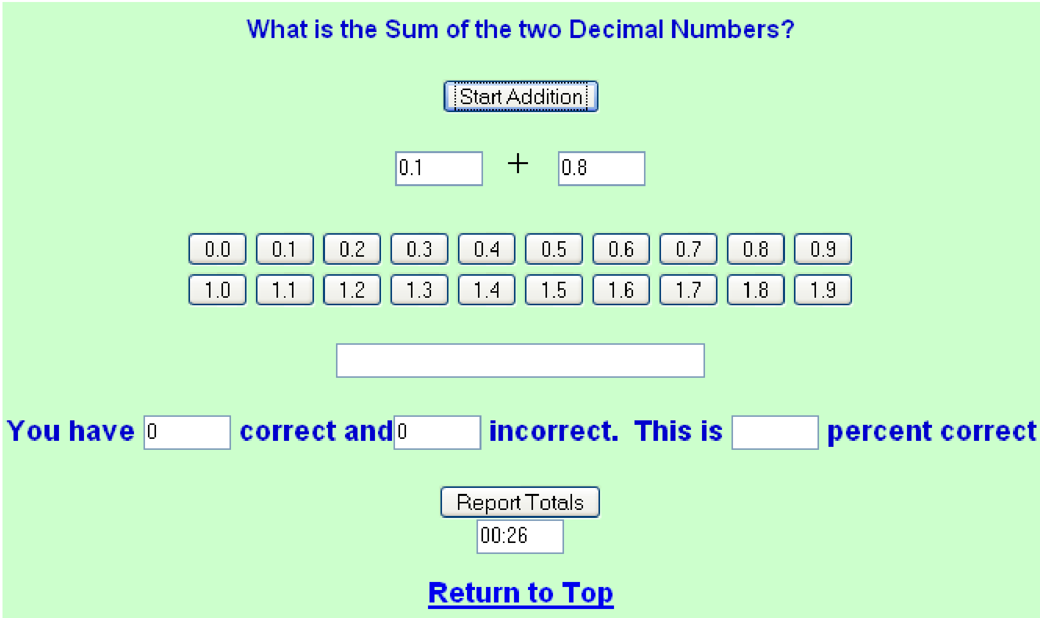

Figure 4.9: AAA Math Addition of decimals tasks.

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.

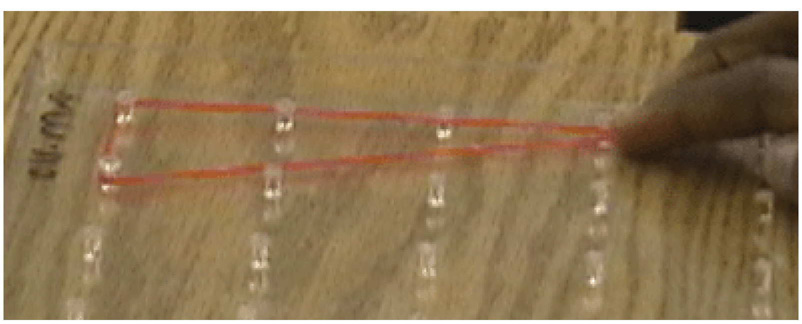

Figure 4.10: One of Shantel's students uses a geoboard to construct a triangle.

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.

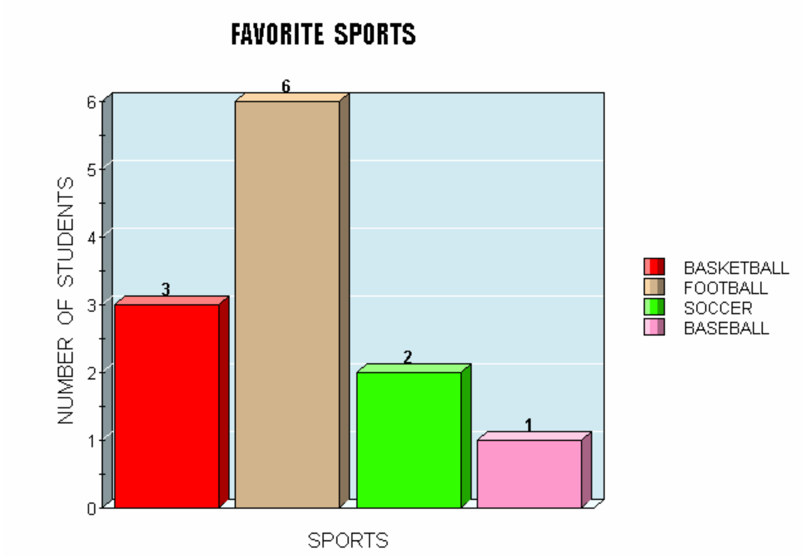

Figure 4.11: A bar graph created by one of Keisha's students.

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.

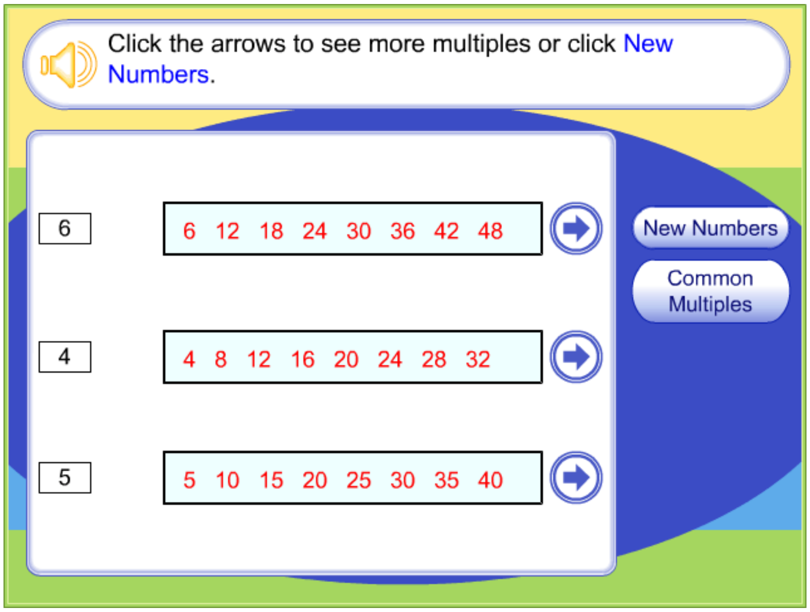

Figure 4.12: Website about multiples and least common multiples.

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.