A DESCRIPTIVE COMPARISON OF ONE UNIVERSITY INSTRUCTOR'S INSTRUCTION DURING PRE-SERVICE MATHEMATICS COURSES AND THE SUBSEQUENT MATHEMATICS AND SCIENCE INSTRUCTION OF THREE OF HIS STUDENTS DURING THEIR STUDENT TEACHING EXPERIENCE

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Introduction

Current recommendations for mathematics education cite the need for instruction which is more student-centered and inquiry-based [1]. One aspect of teacher preparation that should help prepare potential teachers to meet these recommendations is their experience in pre-service mathematics courses [2]. As explained by two respected mathematics educators,

> Pre-service teachers need to have ideas about how to structure classrooms so that they can help their students develop understanding. Since experience is a powerful teacher, it makes sense that these preservice teachers need to learn by experiencing mathematical ways of thinking, reasoning, analyzing, abstracting, generalizing, proving, and applying in environments that model good instruction [3].

The above statement presents a theoretical argument. Such considerations, however, do not provide information concerning how such experiences will compare with the pre-service teachers' subsequent instruction as they begin teaching themselves. One way to do this is to compare descriptions of the instruction students received in their pre-service mathematics courses to that of their own mathematics instruction as they become teachers. This paper involves a qualitative study of one university instructor who teaches mathematics courses for pre-service elementary teachers and three of his students during their student teaching. The study involved describing each participant's instruction according to ten characteristics of inquiry-based teaching. Common aspects of the instruction of the university instructor and the student teachers were then identified. The most prominent characteristics identified in this study involved the use of multiple representations, including concrete manipulatives, and the use of student collaboration, especially within small groups.

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Methodology

The current study took place as part of the Outcomes Research Study of the Oregon Collaborative for the Excellence in the Preparation of Teachers (OCEPT) project funded by a grant from the National Science Foundation. This grant supported a variety of initiatives involving science and mathematics faculty at universities throughout the state over a five-year period. Among these initiatives was an elementary/middle school mathematics strand which focused on helping faculty members improve their instruction in the courses taken by pre-service and in-service teachers. In particular, the project provided a network of instructors who regularly shared methods and materials for making their instruction more student-centered and inquiry-based. At Portland State University (PSU), this included *Math 211: Foundations of Elementary Mathematics I* and *Math 212: Foundations of Elementary Mathematics II*. These two mathematics courses are offered by the mathematics department, and are prerequisites for PSU's Graduate Teacher Education Program in elementary education.

One goal of the Outcomes Research Study was to provide descriptions of the instruction of faculty members involved in the project, and also of some of their students as they became elementary teachers. Case studies of each participant were conducted to provide a qualitative description of their instruction during the 2001-2002 school year. Each participant was observed by the researcher three times during the 2001-2002 school year. During the observations, the researcher took copious field notes. Immediately after each observation, the researcher reviewed his notes and completed an OCEPT-Teacher Observation Protocol (O-TOP) for the observation [4]. After all three observations, the researcher interviewed each participant using the OCEPT-Teacher Interview Protocol (O-TIP)[5]. These interviews were audio taped and later transcribed. From the observation field notes, O-TOP descriptions, and O-TIP transcript a case study composite of each participant was written.

The O-TOP instrument was developed in 2001 by three researchers involved in the study, L. Flick, P. Morrell, and C. Wainwright, drawing on instruments from similar projects and on the body of research involving effective science and mathematics instruction [6-8]. The instrument focused on ten characteristics of O-TOP inquiry-based instruction:

1) habits of mind
2) metacognition
3) student collaboration
4) rigorously challenged ideas
5) student preconceptions and misconceptions
6) conceptual thinking
7) divergent thinking
8) interdisciplinary connections
9) pedagogical content knowledge
10) use of multiple representations

Several possible indicators corresponding to observable actions by both the teacher and the students were described for each of these categories [4] . For example, with regard to student collaboration, the indicators are:

Teacher/Instructor:
- Organized students for group work
- Interacted with small groups
- Provided clear outcomes for the group

Students:
- Worked collaboratively or cooperatively to accomplish work relevant to task
- Exchanged ideas related to lesson with peers and teacher

The degree to which each characteristic was observed during the participant's instruction was gauged globally for each lesson as either N/O (not observed) or from 1 to 4 where "4" means it was highly characteristic of the lesson. The intent of this instrument is not to evaluate the lesson, but rather to provide one part of an overall description that focused on a number of specific characteristics identified with effective inquiry-based instruction. However, since the instrument does include a quantitative aspect, attempts were made to establish inter-rater reliability on the instrument. All of the observers for the OCEPT Outcomes Research Study (four university professors and three graduate students) were trained in the use of the instrument, and a number of initial observations were conducted by multiple observers and then reviewed to evaluate the consistency of the O-TOP ratings. In particular, the researcher at PSU participated in five different joint observations with all but two of the other observers. The few inconsistencies in the different observers' ratings from the joint observations were discussed until consensus was reached. This process established a shared sense of how to use the instrument which minimized the differences of the observers. Since the intent of the instrument was as an aid in the description of the participant and not as a source of data for further quantitative analyses, more formal measures of reliability were deemed unnecessary by the project coordinators.

The interviews were conducted to provide the participants' perspective on their instructional methods. The interview protocol included a number of open-ended questions to elicit the participants' instructional strategies involving the development of thinking skills, social and collaborative skills, as well as content understanding [5]. Their responses provided details concerning not only their preferred instructional strategies, but also of (perceived or real) impediments within the context of student teaching. The student teachers were also asked to comment on their experiences in their undergraduate mathematics and science courses. This provided them with an opportunity to describe their experiences as students in faculty member's classes and how it has or has not affected their instruction as they become teachers themselves.

The researchers realized that a number of intervening factors and limitations inherent in the study make causal comparisons between faculty members and student teachers untenable. For example, the student teachers' experiences in their methods courses, as well as the constraints placed upon them by their supervising classroom teachers, contribute to their instruction. Also, due to limitations in the study, it was not possible to observe the university instructor at the time when the participating student teachers were in his/her classes. Therefore, the case studies were intended to provide descriptions from which possible comparisons could be identified rather than causally established. As such, this research follows the tradition of qualitative methods in educational research in that it is meant to be *suggestive* rather than *definitive* [9].

One PSU mathematics faculty member, "Scott," together with three of his former students, "Toni," "Carol," and "Wendy," agreed to participate in the study (note that the names used here are pseudonyms). All three student teachers had taken *Math 211*, *Math 212*, or both from Scott during the time he was actively involved in the OCEPT project. Julie and Wendy were student teaching in a first grade classroom and Toni was in a fourth grade classroom. Each of the participants were observed by the researcher three times during the 2001-2002 school year, and then interviewed according to the methodology described above. The following composites of each participant were then written from these data sources.

Description of Scores for Each Observation—Scott

Table 1

Composite for Scott, PSU Mathematics Faculty

	OTOP ITEM									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1st Ob	3	4	3	3	3	2	3	2	3	4
2nd Ob	4	3	4	4	4	3	3	2	4	4
3rd Ob	4	3	4	4	4	2	3	3	4	3

Observation 1 — Scott had students work on four word problems which involved different uses for fractions, i.e. part/whole, quotient, and ratio. Students first worked individually, then in their small groups. Each group then made a poster illustrating their solutions to share with the whole class (higher on items 1, 3, 7, and 10). While they worked in groups, Scott moved among the groups listening and asking probing questions (high on items 2, 4, 5, and 9). After a break, Scott led a discussion in which each group explained their solutions using their poster. Scott asked follow-up questions, mostly to draw out ideas and to get the students to focus on the unit (items 1, 2, 4, 6, 7, and 9). Also, as misconceptions arose, such as confusing division by ½ with multiplying by ½, Scott used probing questions to get students to discuss it without "telling" them the "correct" way to think about it (items 1, 5, 6, and 9).

Observation 2 — Scott started with a whole group discussion of a word problem. He drew a picture and discussed several different solutions by writing them on the board and then by soliciting student ideas (high on items 1, 2, 4, 5, 7, and 9). He then asked students to explain why dividing by a fraction is the same as multiplying by its reciprocal. One student volunteered, and explained with help from both Scott and the other students (items 2, 3, 4, and 5). Scott then presented a visual (area) model for multiplying fractions (items 9 and 10).

Scott then started a new topic, decimals, by having them represent different amounts using base ten pieces in their small groups (items 1, 3, and 10). During this activity, Scott moved from group to group, listening and asking questions. He then led a whole group discussion building on the visual model, and used a second visual model (decimal grids) to explain the connection between fractions and decimals. Also, by having them represent 1/3 on decimal grids, he discussed repeating decimals. He then asked if 1/7 is a repeating decimal (most were unsure).

So he had them divide 3 by 7 using long division and discussed the connection (items 1, 5, 6, and 7).

Observation 3 — Scott's first activity involved having students work on a number of word problems involving percents (item 8). They started working individually, and then began sharing ideas within their small groups. In particular, many students were sharing alternate solutions with each other (items 1, 3, 4, and 7). He then had the students discuss the problems with the whole group, stressing multiple solutions (items 2, 4, and 7).

Scott then discussed a more complicated problem involving a discount with the whole group, soliciting and comparing different strategies. He then showed them a particular visual model (percent grids) to represent the problem, and had several students explain their strategy using the model (strong on items 2, 9, and 10). He then asked them to revisit the earlier problems and model each using percent grids, which they did in their small groups (items 3, 9, and 10). After this, he gave them some more complicated problems, such as "A shirt is marked down at a 20% discount, and then by an additional 30% off the already discounted price. What is the total percent discount?" After the students worked on them in small groups, Scott had several students present their solutions to the whole class while he facilitated with probing questions (high on all items).

Patterns and Interpretations

Several things are common to all three observations. The activities were centered on having students work on problems in context, first individually and then in small groups (items 1 and 3). During this time, Scott listened to the students and helped by asking probing questions and by asking them to explain their thinking.

Most students seemed comfortable working on the problems in their groups and sharing their ideas (items 2, 4, 5, and 7). Also, Scott always had several students explain their solutions to the whole group, either using posters or at the overhead. During this time Scott was nonjudgmental, but pointed out important aspects and asked questions. Scott noted in the interview that the "procedure of talking with other people about how they thought about the problem" is the main way he gets students to develop thinking skills. He also noted that collaboration occurs not only within the small groups, but also when students share at the overhead with the whole group.

Another common aspect was the presentation of visual models and manipulatives as one means to represent problems. Interestingly, these models were not presented as "the way," but as one of several useful ways. In the interview, Scott noted that he focuses on developing a solid conceptual understanding by helping students "get a concrete picture in their head of a model" (items 9 and 10).

Influence of OCEPT

Scott noted that his involvement in OCEPT has given him a better awareness of the need for good math teachers and his role in mentoring his students, especially students from underrepresented groups. He also noted the usefulness of getting to know other university faculty around the state who are working on the same kinds of issues.

Additional Comments

After some probing during the interview, Scott also discussed the importance of having students reflect in his classes. Furthermore, he noted that he doesn't make as many connections to other areas (item 8) as he would like, though his use of problems in context helps to some extent.

Description of Scores for Each Observation—Toni

Table 2

Composite of Toni, PSU Student Teacher

	OTOP ITEM									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1st Ob	2	1	3	0	2	1	1	0	2	3
2nd Ob	2	1	2	0	1	1	1	1	2	3
3rd Ob	3	0	4	0	2	1	1	0	2	4

Observation 1 — Items 3 and 10 were higher as she had them work in small groups at "stations" with a variety of manipulatives. The tasks were somewhat open-ended (item 1) and during the lesson she interacted with each group, asking probing questions and helping them when they expressed confusion (items 5 and 9). The remaining items (2,4,6,7, and 8) were low as the tasks (modeling addition equations with manipulatives and then recording them on paper) were mainly repetitive and placed a low cognitive demand on most of the students.

Observation 2 — Item 10 was high as the activity had students create a visual (stair-step) diagram showing the different ways to sum to ten (1+9, 2+8, etc.). Also, even though each student made his or her own diagram, there was lots of interaction between students (item 3). The task, however, was essentially the same as previous ones with smaller sums like six, and therefore was routine for most of the students. Indeed, for many students, the task was essentially one of coloring and minimally connected to mathematics (low on items 1,4,5,6,7,8).

Observation 3 — The first half of the lesson included a number of different activities using manipulatives with a partner (higher on items 1, 3, and 10). During this time, Toni interacted with most of the groups, probing them with directed questions and helping them write equations correctly (items 5 and 9). The second part of the lesson was a whole class game during which they had to answer simple sums (e.g., 6+4) (items 1 and 5). The lesson was reinforcement of previously learned concepts and low on items 2,4,6,7, and 8.

Patterns and Interpretations

A theme of Toni's instruction involves math "stations" where students work on activities in small groups using a variety of manipulatives placed at different spots throughout the room. This type of instruction helps to keep the students actively engaged (item 9).

Toni consistently uses a variety of concrete manipulatives (item 10), staying away from worksheets. In the interview she stated, "I think that they definitely go beyond what would be on a worksheet. They figure out how to solve problems on their own. They are able to say, if they need to group 4 + 3, that they can take 4 dinosaurs and then count 3 more and then add."

Another strong point of her instruction is her use of small groups and pairs (item 3). She notes in the interview that with four or five students at a math station, "sometimes they can work by themselves in that group or other times they will have to develop a pattern with all the members of the group." She generally rotates between groups during the small group activities, asking probing questions and helping students (item 5), which also allows students to discuss their thinking (item 1).

On the other hand, the three lessons observed were all focused on reinforcing concepts the students had previously encountered without much reflection, conjecturing, or connections to other concepts or broader situations. Hence, she scored consistently low on several items, namely

2, 4, 6, 7, and 8. During the interview, she stated that she valued using contextualized story problems in order to support content understanding, but this was not seen during the observations.

Influence of OCEPT

Toni stated that the most influential math class she took was the one taught at PSU by Scott. She noted that her previous experiences with math had been mostly memorization and routine worksheets. "I think that when I took Scott's class it was like the first time that the whole idea of like base 10 made sense to me. He presented it by showing, we were using manipulatives, and all of a sudden it just clicked." She then contrasted this approach to her earlier experience, "I think it is a good way to present it to kids, because like I said, I was good at math, but never really had it presented to me that way. It was like I never thought about it until I took this class." She emphasized the link to manipulatives when teaching place value by stating, "I think it is important that they understand what they are actually adding."

Additional Comments

Toni's use of small groups and manipulatives, while keeping the students engaged, also contributed to a number of classroom management incidents throughout the observations. At times, the students would argue with their partners, and some played with the manipulatives rather than using them in the intended way. During the lessons, she spent extra time with a few of the most unruly students, and was able to keep most of the students on task most of the time. She noted in the interview that a goal of her instruction is to build social skills. She states "our class in particular seems to have a problem working together. So we try to do it often."

Description of Scores for Each Observation—Carol

Table 3
Composite of Carol, PSU Student Teacher

	OTOP ITEM									
	1	2	3	4	5	6	7	8	9	10
1st Ob	3	2	4	2	3	2	2	3	3	4
2nd Ob	2	3	2	0	3	1	4	4	3	4
3rd Ob	3	2	2	2	3	2	4	2	3	2

<u>Observation 1</u> — For a science lesson on electricity (insulators and conductors), Carol gave groups of students a "tester" circuit (battery and wires hooked to a motor in a kit) and a bag of different materials (wood, nail, foil, cardboard, etc.). In these groups, they predicted which materials would complete the circuit, and then tested their predictions (high on items 1, 3, 5, and 10, somewhat on items 4, 6, and 7). Some groups made other discoveries, such as that using two sheets of foil made the motor run faster than using one (strong item 1). After their investigation, Carol asked the whole group what was similar about the conductors (they responded that they were metal). She then had them compare this to a previous activity with magnets (item 8). Then each group went on a "conductor hunt" where they tested a variety of objects in the room (strong on items 3, 9, and 10). During this time, Carol circulated among the room, asking them about their results and suggesting other objects to predict and check (such as the window). After the search, she discussed their results in the whole group, and then noted the similarity/difference between being a conductor and being attracted to a magnet. She had each student name a conductor (item 7) and then read to them about insulated power lines (item 8).

<u>Observation 2</u> — With math, Carol started with a "problem of the day," to form an "H" on their geoboard with a perimeter of 24 units and then find its area (item 10). Carol roamed around as they worked individually and as the students finished, they wrote their names on an "I got it list" at the board. After ten minutes, Carol had several different students explain their solutions, even one girl who had measured the wrong figure (items 5, 7, and 9). She then returned a test they had taken the previous day and reviewed each question. She did this by using questions and by drawing sketches. She also had them review ¼ + ¼ using their rulers (high on items 2, 8, and 10). She also reviewed the difference between degrees F and C by asking questions related to temperature; e.g., "Would it be cold enough to snow if it were 10 degrees C outside?" Also, on some questions she had several students explain their different solutions to the whole class (items 2, 5, and 7).

<u>Observation 3</u> — For the math lesson, Carol started with a problem of the day: "Three kids' ages add to 47. What will be their combined ages in ten years?" As students finished, they wrote their names on the board and then became helpers for the remaining students. Carol noticed that the students had solved the problem in many ways, so she had several of them explain their reasoning (items 1, 5, and 7). She also showed them a different way (the way presented in the answer guide), and discussed a common mistake (item 9). She then had a race to review long division of

whole numbers and decimals. She had the winner explain the solution, and then let them chose a "crazy hat" to wear (items 9 and 10).

For the next activity, she passed out different amounts of unifix cubes to each student, and asked the students to find the average amount in their small groups (items 3 and 10). Carol roamed from group to group checking them and helping them use the algorithm while emphasizing that the sum is not the average. One group split up their cubes evenly, something Carol hadn't expected, and she didn't draw out the link between this and the algorithm. She did, however, have the students discuss some of the shortcuts they used to determine the sum by multiplying when an amount was repeated (items 1, 4, and 7).

Patterns and Interpretations

Carol's use of a "problem of the day" in her math instruction gave students the opportunity to approach a significant problem from a variety of ways. This, combined with the subsequent discussion of different solutions, is reflected in higher scores on items 1, 5, 9, and especially 7 (divergent thinking). She noted in the interview that she liked this method of math instruction because it helps them "work on all kinds of different problem solving processes." This approach of discussing multiple solutions was even used during the review of a test, and it really strengthened student engagement. She also consistently used concrete materials, such as geoboards and unifix cubes, to present problems and to help explain solutions (item 10).

Her science instruction, though only observed once, scored well on most items, though it didn't involve the level of student sharing as in math. Her science lesson, however, presented inquiry-based activities (item 1), were more cooperative (item 3), and more connected to other areas than her math lessons. In both her math and science lessons, she responded well to student ideas and questions and kept the students actively engaged; as she stated in the interview, "It seems like when we just do stuff directly out of the text, it is boring to them" (high on item 9).

Influence of OCEPT

Carol made several references to the positive influence of taking Scott's *Math 211* class. She noted how he focused on the concepts, which helped her because "after you get old enough that that is what it is or you have memorized it, you forget how the concept is." She liked actually using manipulatives for fractions and other concepts that are in the elementary curriculum. She noted, "Scott's class really helped as far as understanding the concept, working in groups." She also noted that she did a lot of reflection in that class, which she likes to do in her own classes, such as having kids reflect on what they learned in math at the end of each week.

Additional Comments

Some of Carol's activities, such as the review of the test in observation 2, were part of the regular teacher's routine.

Description of Scores for Each Observation—Wendy

Table 4
Composite of Wendy, PSU Student Teacher

	OTOP ITEM									
	1	2	3	4	5	6	7	8	9	10
1st Ob	1	2	4	2	4	1	1	4	2	3
2nd Ob	2	1	3	1	3	2	1	4	2	4
3rd Ob	1	2	0	2	0	2	1	3	2	4

Observation 1 — For the math lesson, Wendy started with a whole group discussion about place value (item 5). She then distributed objects (shells, etc.) to each child along with paper cups, and the children counted the objects by making groups of ten (item 10). As they worked, Wendy checked each child, asking them questions to check their progress and to help them stay on task (item 9). Switching to science, Wendy reviewed the previous day's activity on webbed feet (using forks and spoons to stir ketchup). Some of the students explained what happened to the whole group (items 2, 4, and 5). Wendy then discussed "adaptation" and had them think about why a frog needs to swim fast (items 4, and 8). They then saw a video on frogs (item 10). For the last activity, the children worked in groups to make a poster answering questions about one type of animal, such as mammals, fish, birds, or frogs (items 3, 5, and 10).

Observation 2 — In the whole group, the class used the calendar to find sums and differences for the current date (the fifteenth). The students offered several solutions, e.g. 95-80, 7+8, etc. (items 1, 5, and 6). They then reviewed how to write the time using a large clock set to different times (item 8). Then they worked individually on place value problems from a workbook as Wendy moved among them checking their work. As they finished, she had them work in informal groups making stacks of unifix cubes of various multiples of ten, which kept the faster kids engaged (items 3, 9, 10).

Wendy then brought out a large piece of paper and materials to make a "wetlands mural." She first organized the children into groups according to what they wanted to make (fish, trees, owls, etc.). They then worked together as Wendy helped (items 3, 8, and 10). As they worked, Wendy asked them probing questions, such as "What should be in the water and what should be along the shore?" discussing the theme of the mural (frog habitat), and artistic considerations (items 1, 5, 6, and 8). The questions weren't very challenging, however, hence lower scores on items 4 and 7.

Observation 3 — Math began with them writing numbers for the groups Wendy said, such as 74: "I'm thinking of a number with four ones and seven groups of ten." She then had them write the time for different placements of the hands on a clock (all of this was an easy review for the students). Then, she passed out a workbook assignment involving estimation and place value, and moved among the children as they worked individually. Hence, the math portion scored low on most items, particularly items 1 – 7. For science, Wendy discussed "amphibians" with them, and then showed a video of the life cycle of frogs (higher on item 10). After the video, she led a whole group discussion on the stages of a frog's life using a poster and a puppet (items 9 and 10). She also asked them questions about their experiences with frogs; e.g., where would they go to get frog eggs? She also used new vocabulary, "metamorphosis," to practice their reading skills (higher on item 8).

Patterns and Interpretations

In math, Wendy tends to use a variety of activities, including discussions and standard workbook problems along with counting and grouping activities using manipulatives. She also switches between different topics (e.g., between place value and time) in order to keep students engaged. When not using the workbook, she engages the children in more discussion, and allows them to discuss their ideas with each other in the whole group, as with her calendar-based activity.

For the science classes, Wendy uses a wide variety of activities: discussions, posters, videos, the mural-making project, etc. to engage kids in a common theme (all three lessons focused on amphibians). She emphasizes connections to the children's personal life, and also uses science terminology to connect to reading skills (generally high on items 8, and 10). Some of these activities are more open-ended and active and involve a lot of group work (e.g., poster and mural activities). Also, while watching the videos are passive, Wendy used discussions before and after them to engage students more actively. In both math and science, her strongest items are 8 and 10, while the weakest is 7.

Influence of OCEPT

Wendy notes in the interview that she gained "100%" of her ideas and confidence teaching math from her two classes with Scott. She states, "I would be frozen in teaching math without his preparation ... they helped me tremendously ... the way that I encourage them to play ... and construct their own understanding." Her PSU background in science, however, focused on physical science since she already had a background in life science. So, since she's been teaching life science, she notes that the physical science hasn't influenced her teaching much.

Additional Comments

By comparing her math and science instruction, it is clear that Wendy is more comfortable and uses more creativity in her science instruction. Her mixed use of routine workbook activities and more open-ended problems/discussions in math seem to reflect a desire to be more creative (as noted in the interview) that she has not been able to fully realize. However, the workbook she used is part of the regular teacher's curriculum, and it appears that the regular teacher has allowed Wendy more freedom in science than in math.

Comparisons

The above descriptions do not give a comprehensive characterization of the four participants' instruction. They do, however, give some details regarding instances of their instruction with regard to the ten characteristics of inquiry-based instruction. For example, all ten characteristics were generally present in Scott's instruction. Also, while this was not the case for any of the three student teachers, several characteristics were present in their instruction as well. Furthermore, several characteristics that were emphasized in Scott's instruction were also present in the instruction of the students.

Perhaps the strongest similarity in Scott's instruction and that of all three student teachers is item 10, the use of multiple representations. Visual models and/or concrete manipulatives were used in each of Scott's lessons, and were explicitly referred to by him in the interview. All three of the student teachers also consistently used a variety of representations during their instruction. Additionally, both Carol and Toni explicitly referred in the interview to the benefit they gained by using manipulatives in Scott's class.

Another characteristic that was consistently present in Scott's instruction and also evident in all three student teachers was item 3, student collaboration. Nearly every activity in Scott's lessons included some amount of small group discussion, often in combination with individual reflection and whole group discussion. Indeed, Scott noted in the interview that the "procedure of talking with other people about how they thought about the problem" is the main way he gets students to develop thinking skills. All three of the student teachers also included student collaboration in their instruction, generally by having students work in pairs or small groups. It is also interesting to note that Toni valued the use of student collaboration even though it sometimes led to classroom management problems. The possible connection between the student teachers' use of student collaboration and their experience in Scott's class was also highlighted when Carol noted that "Scott's class really helped as far as understanding the concept, working in groups" during her interview.

Other characteristics of Scott's instruction were not as consistently present in the instruction of all three student teachers. Carol's mathematics instruction, however, contained two other important characteristics in common with Scott's instruction, namely items 1 and 7: habits of mind and divergent thinking. Like Scott, Carol gave students non-routine problems to work on, and then had multiple students share their solutions to problems with the whole group. They also both used probing questions to help facilitate these discussions so that a variety of different solutions would be presented and compared. Carol noted in the interview that she liked this method of mathematics instruction because it helps the students to "work on all kinds of different problem solving processes."

One reason why all three student teachers included the use of multiple representations and student collaboration may lie in the relative ease by which these aspects can be addressed. All of the classrooms contained a variety of manipulatives, and the students were generally seated in clusters of four or five desks. The other characteristics, on the other hand, may take more experience before they can be comfortably included by a beginning teacher. Another factor may be the level of students being taught by the student teachers. Both Toni and Wendy were in first grade classrooms, which may have influenced their choice of instruction. Since Carol was in a fourth grade classroom, she may have been more comfortable using more non-routine problems and allowing multiple students to share their thinking with the whole class.

In addition to the characteristics of inquiry-based instruction, another aspect of the student teachers' experience in Scott's class was mentioned in their interviews. All three students mentioned that their experience in Scott's class increased their confidence in both doing and teaching elementary mathematics. Carol made several references to the positive influence of taking Scott's *Math 211* class. In particular, she noted how he focused on the concepts, which helped her because "After you get old enough that that is what it is or you have memorized it, you forget how the concept is." Toni contrasted his approach to her earlier experience and stated, "I think it is a good way to present it to kids, because like I said, I was good at math, but never really had it presented to me that way. It was like I never thought about it until I took this class." His influence was particularly evident in Wendy's interview when she said that she gained "100%" of her ideas and confidence teaching math from her two classes with Scott.

Possible Implications

The descriptions of the participants' instruction in this study suggest that connections do exist between the instruction students received in their pre-service mathematics courses and the subsequent instruction they used during their student teaching experience. Hence, the need for pre-service teachers to learn by experiencing inquiry-based approaches, as exposed by Even and Lappan and reflected in the Professional Standards for Teaching Mathematics, is supported [3,7].

All aspects of effective inquiry-based instruction, however, were not seen to be connected in this study. While all ten aspects of effective inquiry-based instruction were highly characteristic of Scott's instruction, only the use of multiple representations and collaborative groups were consistently characteristic of Toni, Carol, and Wendy's instruction. Other aspects, such as those involving facilitating discussions where students explain their mathematical thinking, were not highly characteristic of Toni, Carol, and Wendy's instruction. This suggests that experiencing inquiry-based instruction in their pre-service classes may not be sufficient for enabling beginning teachers to implement all aspects in their own instruction.

One implication of this may be that pre-service teachers' experiences during their pre-service mathematics courses only "sow the seeds" of the more difficult aspects of inquiry-based instruction. Beginning teachers may need a longer period of classroom teaching experience and other professional development experiences before they are able to incorporate some aspects in inquiry-based instruction. Hopefully, however, by experiencing such instruction themselves during their pre-service classes, they have personally recognized the usefulness of such instruction. A three-year extension of the OCEPT project has begun and will follow a number of teachers, including Wendy, as they begin their teaching careers. This should provide more evidence regarding how connections between Scott and Wendy's instruction do or do not develop over time.

Another implication may be that university faculty, such as Scott, need to explore ways in which students can connect their experiences in his classes to the instruction that they will use in their subsequent teaching. One possibility may be by making the students more aware of the instructional methods he is using in his classes. Perhaps explicit discussions of his inquiry-based "methods" may help the students envision how they could enact these methods themselves as they begin teaching. Research involving this possible implication would be a significant extension to the current study. ■

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