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Student Teachers and Beginning Teachers' Understandings of Scientific Inquiry

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Abstract: This study examined the knowledge and practices of scientific inquiry displayed by three student teachers and two beginning teachers at secondary levels. Observations using the instrument of OTOP designed by the research team of OCEPT (Oregon Collaborative for Excellent in the Preparation of Teachers) generalized similar teaching strategies of scientific inquiry between student and beginning teachers, such as using group work for students' first hand experience, using concrete materials for experimentation or visual tools for demonstration, using questions for factual knowledge mainly without opportunities to understand how scientific knowledge is constructed. Those scientific inquiry activities were very confirmative ones to follow the steps without opportunities of understanding nature of science or nature of scientific inquiry. However, all participants in this study hold knowledge of scientific inquiry envisioned by the *National Science Education Standards* [NSES] (NRC, 1996), where students identify their hypothesis, use critical and logical thinking, and consider alternative explanations through argumentation as well as experimentation. An inconsistent relationship between participating teachers knowledge and practices about scientific inquiry resulted from their lack of pedagogy skills of implementing it in the classroom. Providing opportunities for these teachers to reflect on their beliefs and practices about scientific inquiry was recommended for the future study. Furthermore, increasing college faculty interest in new teaching approaches for upgrading the content knowledge of student teachers and beginning teachers was recommended as a solution, since those teachers showed evidence of influence by college faculties at universities in their pedagogy skills.

Keywords: student teacher, beginning teacher, scientific inquiry, scientific argumentation, OCEPT, OTOP, OTIP

Introduction

Scientific inquiry has a long history in science education. Scientific inquiry is the center of science teaching in the classroom. Students need opportunities to understand how scientific knowledge is constructed by experiencing scientific inquiry envisioned by the *National Science Education Standards* [NSES] (NRC, 1996). Through scientific inquiry, students are supposed to understand the nature of science and the nature of scientific inquiry as well as science concepts while they construct their knowledge by interacting with other peers or teachers who have alternative views or opinions.

However, researchers found that students learn scientific inquiry as a cookbook system to find the right or single answer by following the steps given by teachers rather than as opportunities to share alternative opinions with peers and teachers (e.g., Gallagher & Tobin, 1987). Krajcik et al. (1998) also found that students did not have opportunities to reflect on their data to answer questions and students just arrived at their conclusions without referring to the data.

On the other hand, teachers as participants in some research studies (Crawford, Kelly, & Brown, 2000; Keys & Kenndy, 1999; Krajcik et al., 1998; White & Fredericksen, 1998) were successful in providing students with opportunities to share their alternative ideas by interacting with other peers or teachers in the social practices. Scientific inquiry is not guaranteed by hands-on activities only (NRC, 1996; Kuhn, 1992; Driver, Newton, & Osborne,

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2000). Scientific inquiry must occur by developing reasoning skills through argumentation as well as procedural skills through experimentation so that students can understand how scientific knowledge is constructed,

Then, what is scientific argumentation? Students can develop their scientific thinking skills through scientific argumentation by interacting with peers and teachers in the social context of group experimentations in the classroom (Alexopoulou & Driver, 1996; Herrenkohl et al., 1999). Students in these studies were found to develop their scientific thinking skills through argumentation based on experimentation and observations, where students collect data or evidence to support or refute their hypothesis or theory (Kuhn, 1992). Kuhn also stated that we should experience science as argumentation as well as science as exploration in order to understand the scientific thinking activity of scientists, since students' scientific thinking can be developed best when they practice exercises of describing and justifying theories, presenting alternative theories, presenting counterarguments, and providing rebuttals through argumentations with peers and teachers (Kuhn, 1986; 1993).

Preservice teachers generally experience scientific inquiry teaching for the first time in their science methods course in college and their field experience in the real context of classroom. The problem is that how preservice teachers could teach scientific inquiry without ever having been exposed to inquiry, therefore, they may be uncertain how to teach science using this inquiry method (Reiff, 2001). Most studies (e.g., Simmons et al., 1999; Bowen & Roth, 1999; Roehrig & Luft, 2001) about scientific inquiry teaching employed by preservice and beginning teachers led to problems of teachers not implementing scientific inquiry successfully due to their undefined knowledge or perception of scientific inquiry or due to their lack of pedagogy skills. However, those studies investigated those teachers' teaching strategies that emphasized students' procedural abilities mainly through opportunities of scientific experimentation rather than students' reasoning abilities through opportunities of scientific argumentation.

However, Crawford (2000) investigated one preservice teacher's successful scientific inquiry implementation in the classroom context. The teacher, Deborah, as a participant in the Crawford study provided students with opportunities for scientific argumentation where students could reflect on their hypothesis or theory by interacting with peers or teachers based on their collected data or evidence. However, Deborah was a special case given her 15 years experience of researching as a researcher and 12 years of teaching as a volunteer at schools; therefore, she cannot be representative of preservice teacher's population.

Teachers have a tendency to teach the way that they were taught (Reiff, 2001). If preservice or beginning teachers tend to teach the way that they were taught before learning to teach science as inquiry, then science educators need to be prepared to model inquiry which do not follow traditional roles of teachers as givers and students as receivers. Therefore, the study of preservice and beginning teachers' knowledge and practices of scientific inquiry is a starting point for developing professional programs of scientific inquiry teaching in the classroom, such as teacher preparation courses for preservice, induction programs for beginning teachers, and other inservice programs for experienced teachers.

In this study, I developed profiles of teaching practices displayed by student teachers (STs) and beginning teachers (BTs) and their knowledge about scientific inquiry teaching in the classroom. These profiles of teaching practices employed by STs or BTs provided opportunities to check the alignment between their practices and the envisioned ones by science education reform in order to discover implications for teacher education. I combined STs and BTs together as participants since research (e.g., Roehrig & Luft, 2001) differentiates BTs, who have at most 3 years of teaching experience, from the experienced teachers due to their unpredictable beliefs and practices like those of STs in the classroom. Here, I defined that scientific inquiry teaching is to provide opportunity of scientific argumentation as well as scientific experimentation for students understanding how scientific knowledge is constructed.

The research questions of this study included: (1) What kinds of teaching practices did STs and BTs employ during implementing scientific inquiry? What is their knowledge of scientific inquiry? (2) If any, what relationship can exist between their knowledge and practices about scientific inquiry in the classroom context? (3) Do STs and BTs display different or similar knowledge and practices of scientific inquiry?

Methodology

Sample

I selected two BTs (Amanda, Kelli) and three STs (Jamie, Danielle, & Kelli) for this study based on convenient sampling. Here, Kelli was the only person who had participated in this study for two years. The two BTs were pursuing a teacher certificate program at different universities during academic year, 2001-2002, and they were teaching science at secondary levels academic year, 2002-2003. The three STs were in teacher certificate programs at two different universities and participated in this study during academic year, 2002-2003. All participants were females and taught secondary science levels.

Instruments

I used the OTOP (OCEPT-Teacher Observation Protocol; Morrell, 1999) instrument to determine profiles of reform teaching practices when participants implemented scientific inquiry activities in the classroom. OTOP in Morrell (1999) is an instrument developed by the research team of OCEPT (Oregon Collaborative for Excellence in the Preparation of Teachers) funded by NSF (National Science Foundation) CEPT (Collaborative for Excellence in the Preparation of Teachers) project. The rationale of the NSF CEPT program in general and the OCEPT project in particular is that if preservice teachers have first-hand experience in learning mathematics and science through strategies that are reform-oriented, they are willing to develop both a stronger appreciation for the value of the coursework and use this model for more effective pedagogy when they begin their own teaching. This instrument has 10 categories reflecting the envisioned teaching strategies by the science education reform (NRC, 1996), which includes using technology, using pedagogical content knowledge, checking students' prior knowledge and misconception, inquiry teaching, and understanding habits of mind (Morrell, Flick, Park, et al., 2003a; 2003b). Each category ranges from scale 0, not observed, to 4, higher frequency (Appendix 1). I can see the patterns of reform teaching strategies which participants employed when they taught scientific inquiry through OTOP, such as how much they emphasized the use of technology, how much they provided students with opportunities to discuss their alternative ideas, and how much they connected concept to the examples of real world to help students' content understanding.

Another instrument OTIP (OCEPT Teacher Interview Protocol; Appendix 2) based directly on the OTOP was used to ask five questions. The first three questions were to ask what instructional strategies participants used for the development of students' reasoning skills, their social and collaborative skills, and their content understanding. The fourth question was to ask the teachers as participants if there were other factors in selecting a certain teaching strategy. The fifth question asked what teaching strategies were modeled that participating teachers now use from their undergraduate classes. Using the OTIP as a follow-up instrument acted to validate the observational data and adds an in-depth description of the teacher's perspective.

Data Collection

All STs and BTs were asked to supply the research team with dates and times of possible observation visits. This allowed me to observe an "active" science lessons (lab activity context which participants define scientific inquiry) as opposed to non-targeted content. There were three observations for each participant, then, global scan fieldnotes were taken during each observation, and the OTOP instrument was completed following each observation right away. After the sequences of observations, each participant was interviewed using the interview protocol (OTIP) for 30 minutes. A total of 15 sets of observational fieldnotes, 15 completed OTOP instruments, and 5 interview (30 minutes each audiotaped) transcripts were collected.

Data Analysis

A composite for each participant was developed, summarizing data from the three field observations, the three OTOP instruments, and the one OTIP transcribed interviews. The composite specifically included:

1. A table listing the student teachers OTOP rating for each item for each observation
2. A graph showing the sets of OTOP ratings for comparisons
3. A description of the context
   - Class type/methodology (e.g. lecture, lab, demonstration)
   - Subject content/topic
   - Place in sequence in unit (e.g. introduction, ongoing, review) or relationship of observations (3 consecutive days, etc)
   - Description of students and the class (e.g. junior, sophomore)
   - Institution (middle or high school)
   - Important constraints (number of ESL students, low level class, etc)
4. A description of the scores for each observation
5. Patterns and interpretations of the total data set, depending on observation, OTOP ratings and interview data.
6. Additional pertinent comments/concerns not captured above.

After writing composites for each participant, all case studies were analyzed to see if there was any pattern of reform teaching strategies when STs and BTs taught science as inquiry respectively. OTOP categories, if used reliably across observers to mean the same thing, must be produced with the knowledge of the teaching context. I have been working with OCEPT project funded NSF in a research team at one of Midwestern universities for three years and I have been trained in collecting reliable data using OTOP instrument. When two other researchers and I observed some lessons using OTOP, we found that we have marked all the same scores in all categories except in at most two or three categories of OTOP; however, the difference in scores was only one point. To make up for this difference, we discussed those categories until agreement. This experience suggested that certain reform teaching strategies in the OTOP were more remarkable depending on types of lesson. For instance, inquiry activities implemented by the teachers can be typically characterized as those that use more small groups work, and more technology, and equipment than lecture styles can. Demonstrations by the teachers were characterized with more discussion time through the interactions among students or with teachers.

The OTOP instrument is recognized by the research team of OCEPT as a qualitative dimension with the indicated context of instruction in the classroom. Understanding of how the items of the OTOP performed in the classroom observations must be informed with the context of instruction and teachers perspectives together. In other words, the ratings on the OTOP items are treated as categorical rather than numerical data to generate a profile of what happens across instructional settings rather than assigning scores to a particular context of instruction (Morrell, Flick, Park, et al., 2003a; 2003b). I analyzed the OTOP results in combination with interviews and fieldnotes from each observation to build a preliminary theory of how STs and BTs implemented scientific inquiry in the classroom context. For ease in examining data for the purpose of analysis, the categories were collapsed into three scales as estimates of frequency ranging from "Not Observed" (N/O), "Not frequent" (1 & 2 on the scale of OTOP), to "Frequent" (3 & 4 on the scale of OTOP) to provide the different patterns of teaching strategies between STs and BTs.

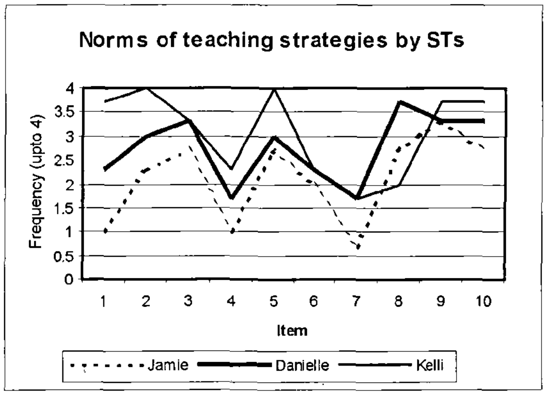
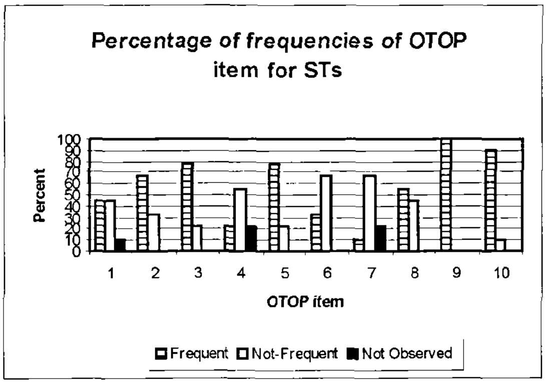


Fig. 1. Three STs profiles of teaching strategies.



Items of OTOP

(1) Habits of mind (2) Metacognition (3) Student discourse and collaboration (4) Rigorously challenged ideas (5) Student preconceptions and misconception (6) Conceptual thinking (7) Divergent thinking (8) Interdisciplinary connections (9) Pedagogical content knowledge (10) Multiple representations of concepts

Fig. 2. Mean percentage of frequencies of OTOP by STs.

Results

Profiles of Reform Teaching Strategies Used by STs and BTs

First of all, the inquiry lessons taught by three STs in this study were characterized by group work or demonstration mainly. The observed inquiry lessons consisted of pre- or post-lab only or whole lab sequences from pre to post-labs. The science content taught by STs included physics, chemistry, and life science. There was not any ESL (English Second Language) student or special student who had disabilities in their learning and all observations were made at secondary levels. Nine observations with OTOP and fieldnotes produced a profile of teaching strategies used by three STs. Each profile was based on three observations of each participant as a mean frequency that showed certain reform teaching strategies in the context of scientific inquiry (Fig. 1).

In Figure 1, typical STs' reform teaching strategies in the context of scientific inquiry included item #2 (Metacognition), 3 (Student discourse and collaboration), 5 (Student misconception), 8 (Interdisciplinary connections), 9 (Pedagogical Content Knowledge: PCK), and 10 (Multiple representation of concepts).

The three STs started the lesson by reviewing the content covered in the previous lesson with questions to check their prior knowledge or misconception (#2 & 5). However, those questions tended to elicit factual knowledge rather than encourage students' divergent thinking. STs' lab activities with demonstration and group work (#3) were confirmative ones (#8 & 10) rather than guided or open ones where students could understand how scientific knowledge is constructed through alternative ideas or anomalous data. These teaching profiles displayed in the context of scientific inquiry were characterized by students physical experience only through group work or by examples connecting to the real world, focusing more on concrete materials and visual tools and focusing less on opportunities for discourse to understand science as human endeavor. Notes on STs' composites from OTOP, fieldnotes, and interviews supported these results as seen in the following, which implied first of all that scientific inquiry is to find the definite single and right answer.

> Green checked the answers with students. The worksheets included 10 questions and Green checked if students got right answers. Students graded each question with points. Those questions were factual knowledge ones (ST Greens composite)

Here, Green, one of the STs, worked with her students to check their right or single answers through questions. The following note from composite implied that the scientific inquiry is confirmation one to follow the steps rather than open one to design the experiment.

> Her (Kellie) lesson always included a lab activity for students direct experience in getting the scientific concept, but the lab activity was not an open inquiry one, but a confirmation inquiry opportunity where students could confirm the results through hands-on activity, which made score a little low (2 or 3) in item 4 & 7 (challenged ideas and divergent thinking) for students to express different ideas or critique others' ideas. However, there were opportunities where students could conduct some inquiry steps such as collecting data, representing the data, interpreting, and presenting the data (ST Kellis composite).

The composite above describes how Kelli emphasized the use of procedural skills through opportunities for experimentation rather than reasoning skills through opportunities for argumentation. Jamie, one of STs, perceived that the scientific inquiry is to provide students with first-hand physical experience in the following.

> A movie was shown which included cases and examples of gravity. For example, there were two balls falling to the floor. There was introduction of history of science, such as Galileo's experiment from Pisa's tower. All contents were connected to students' experiences from the real world such as roller coaster. [....] There were more examples, such as the relationship between the sun and earth and a merry-go-round. The movie provided the story of scientists who research gravity. The movie included all kinds history of science related to gravity and cases/examples related to gravity (ST Jamies composite).

In this description, Jamie provided examples that were connected to the students' physical experience from real world for their content understanding. The interview in the following also supported Jamie's knowledge of scientific inquiry as first hand experiences.

> Yeah, real world experience to the concepts. Thank you for reminding me, because we talked about that. We talked about Mt. St. Helens, for instance, when we were talking about plate tectonics, and just how, even though none of them had personally experienced that, their parents probably had. Or talking about, "OK, you like to go skiing on Mt. Hood or doing whatever you do at Mt. Hood and what happened if that erupts. How will it affect?" so things that they are familiar with them [.....] Oh, yeah, the toys right. Also things are very familiar to them. Toys, they never would think that they would even be able to use their baby toys to understand physics, about acceleration and things like that (Jamie's Interview, 5/23/03).

Here, Jamie perceived that it is important for students to understand the content through the examples from the real world.

When the five-point scale of OTOP was collapsed to a three-point scale with percentages to combine three STs' profiles, these five teaching strategies were more generalizable (above and 50%) than the other items of OTOP (see Fig. 2). Again, STs did not use the teaching strategies of item #4 (Rigorously challenged ideas), 6 (Conceptual thinking), and 7 (Divergent thinking) that could scaffold students to construct and reflect on their alternative opinions through which they can understand how scientists construct scientific claims as one aspect of scientific literacy.

Looking at the BTs observations, there were a number of OTOP categories which were typical teaching strategies displayed in the context of scientific inquiry and these teaching strategies were similar to those of STs. Two items, #2 (Metacognition) and 9 (PCK), were highly preferred by BTs during scientific inquiry teaching. The following items #3 (Student discourse and collaboration), 8 (Interdisciplinary connections), and 10 (Multiple representations of concepts) were also moderately *used by BTs (see Fig 3). This profile is more* remarkable in Fig. 4 indicating that item #2 (Metacognition), 3 (Student discourse and collaboration), 8 (Interdisciplinary connections), and 9 (PCK) of OTOP were typical patterns of reform teaching strategies, frequently used (over 50%) by BTs in the context of scientific inquiry.

BTs rarely used the following teaching strategies, item #1 (Habits of mind), 4 (Rigorously challenged ideas), 5 (Student misconception), 6 (Conceptual thinking), and 7 (Divergent thinking), which marked "Not Observed" or over 50 % of "Not Frequent" use. These results also indicated that BTs implemented confirmative inquiry activities with concrete lab materials or visual tools and without opportunity for students to construct their own different ideas through discussion. Composites from OTOP, fieldnotes, and interviews displayed these results. The following note implied that the scientific inquiry is hands-on activity.

> Her inquiry lab was very confirmative, so she did not scored high in item #1. However, she scored high in item #10 about concrete materials or visual stuffs needed to do lab activity or individual worksheet. And she scored a little high (3 two times) in item #4, group work for hands-on activity and she scored low when students worked on individual worksheets (OTOP). Students tried to figure out whether that material was based on some properties provided by one student or more than one student). There were interactions to guess what that material was. Students got all papers including continent models for their own activities and she let students read

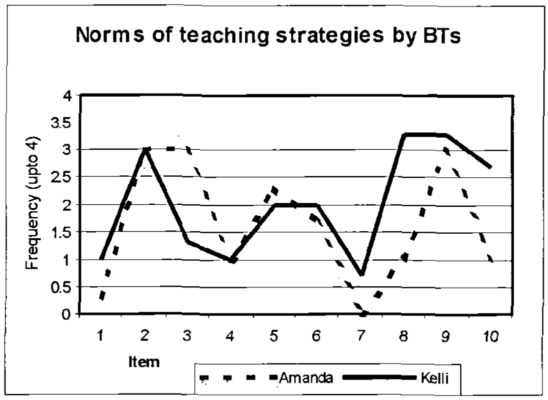
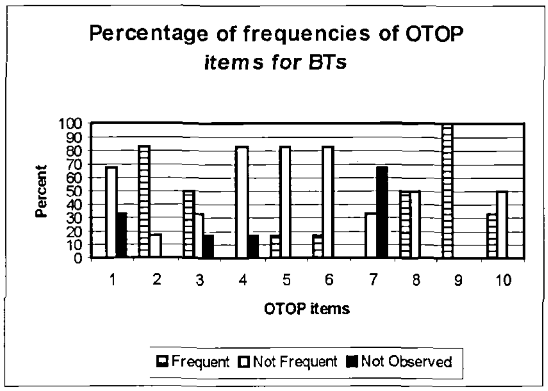


Fig. 3. Two BTs profiles of teaching strategies.



Items of OTOP

(1) Habits of mind (2) Metacognition (3) Student discourse and collaboration (4) Rigorously challenged ideas (5) Student preconceptions and misconception (6) Conceptual thinking (7) Divergent thinking (8) Interdisciplinary connections (9) Pedagogical content knowledge (10) Multiple representations of concepts

Fig. 4. Mean percentage of frequencies of OTOP by BTs.

the instruction before activity. (BT Amanda's composite)

Here, Amanda's inquiry activities consisted of hands-on ones with concrete materials and visual tools. The Amanda's quote from her interview also supported her knowledge of scientific inquiry as hands-on activity.

We gave a lot of different ways to do what? I guess one, the main one I love is labs, because the students get to find the content out in a real-life setting. [.....] Another way of something concept would just be in making it as hands-on and as contextual as I possibly can. [.....] Another thing I kind of modeled after was we learned so much from labs, especially in science. I try to make labs as often as I can in the classroom because that is where the real discovery and inquiry comes in. (BT Amanda's interview, 2/21/03)

Again, Amanda perceived that inquiry occurs through students' physical experience from hands-on activities in the real life context. The following notes from the other's composites implied that the scientific inquiry is a process of following steps as indicated.

Students started to work together, but they did not share their ideas. They just checked with each other to see if they underlined the right sentences for pre-lab. Kelli explained some controls expected from their activities. She asked if they understood what they would do during activities and students evaluated their understanding based on their reading and content that they learned last time. [....] She also provided information how to weigh Mg precisely. She presented all information needed for students to follow up on the procedures. (BT Kelli's composite)

Here, Kelli's implementations of scientific inquiry consisted of checking students prior information and their procedural skills before activities.

The relationship between their knowledge and practices about scientific inquiry

Both STs and BTs displayed teaching practices *inconsistent* with their knowledge of scientific inquiry envisioned by the *Standards*. For example, all participants in this study understood that students need to have opportunities to learn science as inquiry through experimentation in groups or in peers. For this purpose, all participants organized hands-on activities or demonstrations, through which students could understand the way of knowledge construction and science as inquiry or human endeavor. However, the hands-on activities that teachers implemented were very confirmative ones which demanded low cognitive levels without argumentation opportunities. The following case of each ST and BT showed how their knowledge of scientific inquiry was inconsistent with their practices of scientific inquiry in the classroom.

BT Kelli's Case

Kelli perceived that understanding the nature of scientific inquiry and the nature of science, such as subjectivity with alternative opinions, are important. She also understood that inquiry must be open with alternative ideas and that science is the way of knowing as human endeavor. However, her practices of inquiry were very confirmative with little chances for students to learn these aspects. The OTOP and fieldnotes showed that her practices in the context of inquiry put the emphasis on low cognitive demand for students reasoning skills, on the use of concrete materials or visual tools, and on the following procedures pursuing the right or single answer (composite).

She scored low (0, 1, or 2) in item number 1 about habits of mind, item number 4 about rigorously challenged ideas, and item number 7 about divergent thinking related to science as endeavor (three OTOPs). During the discussion time after lab, students checked their answers in two tables and one student asked the other one about why he got those answers. [.....] This activity is very confirmative work to calculate the volume of H_2 using gas laws formula. No alternative opinions from their investigation (2nd Ob fieldnotes)

Instead of giving them answers, try to lead them down a path so that they will be able to have, like for example, figuring out how to balance a compound. I don't just say, they ask me if that is right, and I will say, yes or no, and I make them figure out why it is right. I try to get them to have a kind of a scheme of how they can figure it out by themselves. Now that we are doing solutions, after we did all that, they understand it a lot better. [.....] The other major science kind of stuff that we try to do is we have talked a lot about science being subjective and about the fact that it really depends on the scientists, and that two people can come up with totally different answers, depending on how you set up your investigations and things like that (Interview, 4/8/03).

ST Danielle's Case

Danielle emphasized the use of hands-on activities for students' learning to understand epistemological aspects of scientific knowledge in her interview and she implemented many hands-on lab activities during her lessons. However, her inquiry lab was also a highly confirmative activity without opportunities for divergent thinking or expressing alternative ideas based on Danielles composite and her interviews.

Danielle scored 0 in the 2nd observation in item number 4 and 7 about students alternative ideas or challenged ideas (OTOP). Students in groups or in pairs worked with each other to check and inform other students of some ideas. However, this is not a chance for inquiry or critiques (1st ob fieldnotes). She demonstrated how to cut the earthworm step by while looking inside the internal structure of earthworm. This activity is a very confirmation one (not inquiry opportunities for alternative interpretation), since those questions in the lab report were to ask factual knowledge (not higher level questions). Students answered questions in the lab report and most of them were asking factual knowledge (2nd ob fieldnotes). The students did very little in the way of thinking about their learning. The teacher did ask for answers to the dissection lab questions and students responded in their own words and identified mostly identification and procedural type clarifications (3rd ob fieldnotes).

In that lab time, they would mostly leave it up to us to actually do the experiment or the inquiry. In my geology classes and one of my biology classes, I had a lot more hands-on activities, where we would lay the materials out on the table and they would go for it. [.....].where you put everything on the table and said, "Go for it" and you pick out what you want, and you tell me what you think it is versus the step-by-step through the lab. [.....] I really do like the part where they just said, "You investigate. Go for it". I definitely pulled more out of the labs than the lectures (Interview, 6/03)

As far as my learning, I am a definite hands-on learner and I guess since I learn that way, I try to have my classes run that way. I try really hard to incorporate all those different things-listening, visualizing, hands-on. But from the feedback that I got back from my kids, they seem to like the hands-on, inquiry-based learning the best (Interview, 6/03).

The Difference Between STs and BTs in their Knowledge and Practices of Scientific Inquiry

Fig. 5 below the extent of shows if there was any differences in both STs and BTs' reform teaching strategies displayed in the context of scientific inquiry. Both STs and BTs used most teaching strategies of OTOP item #2 (Metacognition), checking students prior knowledge and encouraging them to express their ideas, and #9 (PCK), using alternative lecture types such as demonstra-

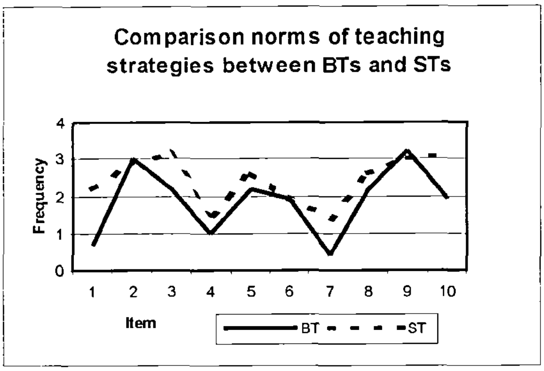
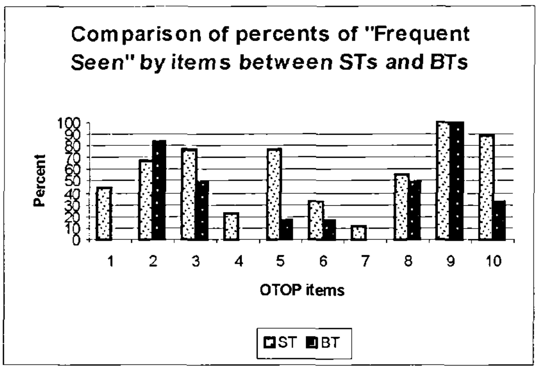


Fig. 5. Instruction comparison b/t STs and BTs.



Items of OTOP

(1) Habits of mind (2) Metacognition (3) Student discourse and collaboration (4) Rigorously challenged ideas (5) Student preconceptions and misconception (6) Conceptual thinking (7) Divergent thinking (8) Interdisciplinary connections (9) Pedagogical content knowledge (10) Multiple representations of concepts

Fig. 6. Frequencies of instruction used by STs and BTs.

tion, individual work, pair or group work, and video watching. Fig 6 compared the percentage of "Frequently Seen" in items displayed by STs and BTs indicating the same patterns of teaching strategies in the context of scientific inquiry by Fig 5.

In the case of STs, they tried to focus on students' understanding of nature of science and provide inquiry activities more when compared to BTs (item #1: Habits of mind). STs also checked students prior knowledge or misconceptions more often by questioning before new concept introduction (item #5: Student misconceptions). In addition, STs used concrete materials or visual tools for students concept understanding more often than BTs (item #10: Multiple representations of concepts).

In the case of BTs, teachers infrequently used teaching strategies that could facilitate students' understanding the nature of science or scientific inquiry through opportunities of discussion or argumentation to see how scientists carry out their experimentation or how scientific knowledge is constructed (item #1: Habits of mind, #4: Rigorously challenged ideas, and #7: Divergent thinking)

Conclusion and Discussion

The profile of reform teaching strategies displayed by STs and BTs in the context of scientific inquiry has been developed. It has highlighted the strengths and weaknesses in the use of reform-oriented teaching strategies in those teachers' classroom context of scientific inquiry. Surely some teachers were doing more or less reform teaching than others. STs, regardless of their grade level or subject content, displayed typical patterns of teaching strategies consisting of questioning at review time (#2 & 5 of OTOP), teachers' demonstrations (#10), introduction or information of new knowledge or procedural skills, and group activity or individual worksheet to confirm or check the ready made answers (#3) with appropriate practices and information (#9). All STs responded in their interviews that it was possible to include some hands-on activity to facilitate students' concept understanding; however, their reform teaching strategies in the context of scientific inquiry was different from what the *Standards* has envisioned. All STs in this study rarely provided students with opportunity for argumentation to understand how scientific knowledge is constructed by differentiating and coordinating their theories and data collected from their experimentation (Kuhn, Amsel, & OLoughlin, 1988; Gallagher & Tobin, 1987).

This tendency of confirmative inquiry practices without opportunities for argumentation was more evident in BTs' cases. BTs' teaching strategies in the context of scientific inquiry were characterized by "Not Frequent" seen or "Not Observed" in the categories *Habits of mind* (#1), *Rigorously challenged ideas* (#4), and *Divergent thinking* (#7) in Fig 6. BTs more often used traditional teaching strategies, such as lectures or individual worksheets, rather than opportunities of discussion or argumentation for students to understand the nature of scientific inquiry, the nature of science, or the nature of argumentation. In addition, in their classes did not show much evidence of encouraging students to solve the problems, challenge peers or teachers ideas, or engage in divergent thinking. However, in their interviews, BTs displayed their knowledge of scientific inquiry envisioned by the *Standards* (NRC, 1996) to some degree.

Overall, both STs and BTs displayed similar patterns of reform teaching strategies in the context of scientific inquiry, even though there was a little difference in the frequencies of use. For the scientific inquiry teaching and learning, both STs and BTs used teaching strategies that emphasized students' experience itself rather than students' cognitive development to understand how the knowledge is constructed. About the knowledge of scientific inquiry, both STs and BTs as participants perceived that students should be provided opportunities to experience minds-on activities through argumentation as well as hands-on activities through experiments. However, teachers as participants in this study carried out highly confirmative inquiry activities and students did not have chances to express alternative ideas by confirming or refuting their hypothesis with their data during their scientific experimentation. That is, the teaching strategies employed by those teachers in the context of scientific inquiry did not provide students with chances to reflect on conclusions based on their data to see if students collected data appropriate to answer the questions or if students concluded findings using their own collected data.

The possible reasons why ST and BT showed somewhat different reform-based teaching strategies in the context of scientific inquiry can be explained with some components. When the researcher had communication with beginning teachers as participants in this study, they complained about the heavy curriculum they were expected to cover during the academic year or about classroom management skills they needed to acquire, which could be factors that influenced their selection of more directed teaching strategies. Those factors by BTs, heavy curriculum to cover and classroom management skills, were not what student teachers felt heavy duty in their field experience. Additionally, the grade levels or classroom contexts, such as large class size or lower level students, could be other factors to make beginning teachers reluctant to use students discourse or a collaborative teaching strategy (Schepige, Morrell, & Wainwright, 2004).

Implication

Scientific inquiry envisioned by the *Standards* is not guaranteed by hands-on activities only. Students need to have opportunities to learn science as inquiry by minds-on activities through argumentation as well as hands-on activities through experimentation. The findings of this study provide a direction for further scientific inquiry research.

First of all, if teachers start to form their knowledge in the early stage of their teaching careers as student teachers or beginning teachers, it is important to provide opportunities in which they can reflect on and develop a firm understanding of inquiry teaching. Research has found that teachers' constructivist epistemology is a pivotal component in implementing scientific inquiry (Maor & Taylor, 1995; Mackenzie, 2001). Teachers as participants in Maor & Taylor (1995) and Mackenzie (2001) provided students with opportunities to share their ideas or express alternative ideas in constructing their theories using data collected though inquiry activities rather than follow the procedures given by teachers to confirm ready-made answers. About STs and BTs' understanding of scientific inquiry in this study, they seemed to hold knowledge envisioned by the *Standards* (NRC, 1996) to some degree, but there was limitation in methodology to investigate their understanding or knowledge of scientific inquiry further.

Second, teachers need to learn more pedagogical skills of scientific inquiry in order to implement it successfully. Some studies showed how teachers were successful in implementing scientific inquiry for students' opportunities for argumentation, through which students learned how to deal with anomalous data as supportive or refuting ways of constructing their theories (Crawford, 2000). Crawford, Kelly, & Brown (2000) and Keys & Kennedy (1999) reported that teachers were successful in implementing scientific inquiry in the classroom with some models of their own design in which they provided some prompts or clues so that their students could reflect on and evaluate their learning through argumentation. For the development of pedagogy skills for scientific inquiry, teachers need to talk with other teachers about what kind of instructional activities are used, what kinds of assessment activities are needed, and what kind of reasoning skills students need to develop. Therefore, teacher education programs need to pursue the development of curricular and instructional activities that foster the attitude or skills necessary for teachers to transform their understanding of scientific inquiry into classroom practices through professional developmental programs for STs and BTs.

Finally, when STs and BTs in this study were asked if they used any teaching strategy modified from strategies used by college faculty in their undergraduate classes, they all responded that undergraduate preparation courses contributed to their instructional design and practices now in the classroom.

In two of my professors' classes in science they did make it contextual. They brought in all of theses reading from outside. We were going places, doing field studies. They connected to the real world. So I tied that in a few different ways. I guess one would be that my students are also doing science-reading project. They were able to choose their own book and it can be fiction or nonfiction and they are reading it. It has to be something that applies to real life (ST Amanda interview, 2/21/03).

I think the one thing that impressed me probably the most that I think is really important is to use variety, to not rely on just labs, don't rely on lecture, don't rely on demonstrations. Do a little bit of both. [......] They[students] like the pace of the class and the differentiation of things. I am not very good at doing demonstrations yet. Every time I do one, sometimes it doesnt always work and sometimes it does. The kids are always proud of me when I try. [......] I also use a variety of assessment. We don't have just tests. We have projects, we dont have just have lab write-ups. In fact, sometimes we have labs that are nothing but observation (BT Kelli's interview, 4/8/03).

This evidence implied that teachers preparation program or courses at college or university levels are potential factors that influence STs and BTs' choice of teaching strategies for science teaching and learning. Student teachers and beginning teachers who participated in this study commented that specific teaching strategies used by some instructors at colleges or universities influenced the teachers decision in selecting instructional strategies. Therefore, increasing college faculty interest in new teaching approaches for upgrading the content knowledge of future and practicing teachers holds promise.

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Appendix 1

OCEPT-Teacher Observation Protocol (O-TOP)
Outcomes Research Study 2002

This instrument is to be completed following observation of classroom instruction. Prior to instruction, the observer will review planning for the lesson with the instructor. During the lesson, the observer will write an anecdotal narrative describing the lesson and then complete this instrument. Each of the ten items should be rated globally; the descriptors are possible indicators, not a required check-off list.

	Not Characterizes				Observed Lesson
1. This lesson encouraged students to seek and value various modes of investigation or problem solving. (Focus: Habits of Mind)	N/O	1	2	3	4
Teacher/Instructor: Presented open-ended questions Encouraged discussion of alternative explanations Presented inquiry opportunities for students Provided alternative learning strategies Students: Discussed problem-solving strategies Posed questions and relevant means for investigating Shared ideas about investigations					
2. Teacher encouraged students to be reflective about their learning. (Focus: Metacognition-students' thinking about their own thinking)	N/O	1	2	3	4
Teacher/Instructor: Encouraged students to explain their understanding of concepts Encouraged students to explain in own words both what *and* how they learned Routinely asked for student input and questions Students: Discussed what they understood from the class *and* how they learned it Identified anything unclear to them Reflected on and evaluated their own progress toward understanding					
3. Interactions reflected collaborative working relationships and productive discourse among students and between teacher/instructor and students. (Focus: Student discourse and collaboration)	N/O	1	2	3	4
Teacher/Instructor: Organized students for group work Interacted with small groups Provided clear outcomes for group Students: Worked collaboratively or cooperatively to accomplish work relevant to task Exchanged ideas related to lesson with peers and teacher					
4. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. Focus: Rigorously challenged ideas)	N/O	1	2	3	4
Teacher/Instructor: Encouraged input and challenged students' ideas Was non-judgmental of student opinions Solicited alternative explanations Students: Provided evidence-based arguments Listened critically to others' explanations Discussed/Challenged others' explanations					
5. The instructional strategies and activities probed students' existing knowledge and preconceptions. (Focus: Student preconceptions and misconceptions)	N/O	1	2	3	4

Teacher/Instructor:
- Pre-assessed students for their thinking and knowledge
- Helped students confront and/or build on their ideas
- Refocused lesson based on student ideas to meet needs

Students:
- Expressed ideas even when incorrect or different from the ideas of other students
- Responded to the ideas of other students

6. The lesson promoted strongly coherent conceptual understanding in the context of clear learning goals. (Focus: Conceptual thinking)	**N/O**	1	2	3	4

Teacher/Instructor:
- Asked higher level questions
- Encouraged students to extend concepts and skills
- Related integral ideas to broader concepts

Students:
- Asked and answered higher level questions
- Related subordinate ideas to broader concept

7. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence. (Focus: Divergent thinking)	**N/O**	1	2	3	4

Teacher/Instructor:
- Accepted multiple responses to problem-solving situations
- Provided example evidence for student interpretation
- Encouraged students to challenge the text as well as each other

Students:
- Generated conjectures and alternate interpretations
- Critiqued alternate solution strategies of teacher and peers

8. Appropriate connections were made between content and other curricular areas. (Focus: Interdisciplinary connections)	**N/O**	1	2	3	4

Teacher/Instructor:
- Integrated content with other curricular areas
- Applied content to real-world situations

Students:
- Made connections with other content areas
- Made connections between content and personal life

9. The teacher/instructor had a solid grasp of the subject matter content and how to teach it. (Focus: Pedagogical content knowledge)	**N/O**	1	2	3	4

Teacher/Instructor:
- Presented information that was accurate and appropriate to student cognitive level
- Selected strategies that made content understandable to students
- Was able to field student questions in a way that encouraged more questions
- Recognized students ideas even when vaguely articulated

Students:
- Responded to instruction with ideas relevant to target content
- Appeared to be engaged with lesson content

10. The teacher/instructor used a variety of means to represent concepts. (Focus: Multiple representations of concepts)	**N/O**	1	2	3	4

Teacher/Instructor:
- Used multiple methods, strategies and teaching styles to explain a concept
- Used various materials to foster student understanding (models, drawings, graphs, concrete materials, manipulatives, etc.)

Appendix 2

OCEPT Teacher Interview Protocol (O-TIP)

(1) Student thinking: How does your instruction support development of thinking skills?

(2) Social skills & collaboration: How does your instruction support development of social and collaborative skills?

(3) Content: How does your instruction support development of content understanding?

(4) Instruction: Besides student thinking skills, content understanding, and social/collaborative skills, what else guides your selection of instructional approaches?

(5) Additional Questions: In your undergraduate classes, what strategies were modeled that you now use? How did your undergraduate preparation contribute to your instructional design and practice?