

Pre-service Teachers' Views of Inquiry Teaching and Their Responses to Teacher Educators' Feedback on Teaching Practice

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This study attempted to explore 15 Korean elementary pre-service teachers' views of inquiry teaching. During a science teaching methods course, pre-service teachers implemented a peer teaching lesson, had a group discussion to reflect on five teacher educators' comments on their first peer teaching practice, and revised and re-taught the lesson as a second peer teaching practice. The results indicate that pre-service teachers changed their views of inquiry teaching from following the process of inquiry or a completely unstructured discovery approach to facilitating students' inquiry learning with instructional guidance. The importance of reflective group discussion and re-teaching a lesson is discussed.

Keywords: Pre-service teachers, reflective discussion, inquiry teaching, peer teaching, teacher educator's feedback

INTRODUCTION

There have been various efforts and approaches in teacher education programs and research communities to enhance science inquiry teaching since the 1960s. The inquiry approach is thought to be a way to develop

scientific knowledge and scientific habits of mind even though students are not at the same level of doing science as a scientist (Handelsman et al., 2004). This shifts the focus of science teaching from the body of content knowledge to the process of thinking and building knowledge based on the inquiry process, which is aligned with a constructivist understanding of knowledge and learning (Llewellyn, 2001). And yet, it has been a challenging task for teachers to conduct inquiry teaching effectively and efficiently in classroom situations (Anderson, 2002; Kielborn & Gilmer, 1999; King, Shumow, & Lietz, 2001). Various challenges have

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State of the literature

- It has been a challenging task for teachers to conduct inquiry teaching effectively and efficiently in the classroom.
- There are differences in pre-service teachers and teacher educators' views of inquiry teaching and pre-service teachers are not passive recipients of teacher educators' feedback.
- Pre-service teachers' belief systems are yet to be firmly established, and thus pliable enough to bring forth changes toward inquiry teaching.

Contribution of this paper to the literature

- Pre-service teachers' reactions to teacher educators' feedback on their peer teaching practice were either to ignore or reject the feedback.
- Written feedback or reflective discussion alone was not sufficient enough to change pre-service teachers' views of inquiry teaching.
- Pre-service teachers' experience of re-teaching a lesson after reflective discussion helped them accept teacher educators' feedback and change their views of inquiry teaching.

been identified, such as teachers' frustration and confusion in inquiry instruction, misconceptions in students' understanding (Brown & Campione, 1994; de Jong et al., 2005), lack of resources, and a misalignment between curriculum and assessment (Kim, Tan, & Talaue, 2013). Among those challenges, teachers' beliefs or knowledge are one of the main influential factors on decision making and actions of inquiry teaching (Brown, Abell, Demir, & Schmidt, 2006; Keys & Bryan, 2001; Llewellyn, 2001). Since empirical research findings support that beliefs and knowledge are intertwined with reciprocal impact when teachers make decisions about their teaching (Bryan & Abell, 1999), we prefer the term *view* to describe the interplay of beliefs and knowledge (Crawford, 2007). In this study, we attempt to examine pre-service teachers' views of inquiry teaching through the lens of their peer teaching practices and their responses to teacher educators' feedback in order to discuss the further development of inquiry science teaching in teacher education programs.

Teachers' views of inquiry teaching

Researchers on teachers' beliefs and inquiry teaching practice (e.g., Luft, 2001, 2009; Pajares, 1992; Palmer, 2006; Roehrig & Luft, 2006; Simmons et al., 1999; Tobin & McRobbie, 1997; Tsai, 2002) discuss the ways in which teachers' beliefs are complexly interrelated with their actions; hence, beliefs need to be delved into in order to improve their teaching in intended directions.

Research suggests that both pre-service and in-service teachers hold a wide range of beliefs about inquiry teaching (Brown et al., 2006; Brown & Melear, 2006; DeBoer, 2004). Many teachers understand inquiry teaching as hands-on activity (King, Shumow, & Lietz, 2001). Some teachers believe inquiry teaching is a student-driven activity and some believe there must be a research question generated from either a teacher or students to conduct inquiry (Brown et al., 2006; DeBoer, 2004). Researchers state that these beliefs are critical bases of teachers' practice of inquiry teaching in classrooms.

Pre-service teachers' beliefs about teaching are often established based on their personal and sociocultural experiences even before they enter a teacher education program (Pajares, 1992). Their views on inquiry teaching shaped from previous science learning experiences are difficult to change (Crawford, 2007; Koballa, Glynn, Upson, & Coleman, 2005). However, their belief systems are yet to be firmly established, and are thus pliable enough to bring forth changes toward inquiry-based science teaching (Luft, 2001, 2009; Roehrig & Luft, 2006). Previous research suggests it is significant for pre-service teachers to experience and practice actual teaching and reflect on the dynamics of decision making, actions, and interaction through and after teaching practice in order to develop deeper views of inquiry teaching (Anderson, 2002; Crawford, 2007; Mule, 2006).

Teaching experiences through practicum or peer teaching practice in a teacher education program are believed to provide meaningful opportunities to learn, reflect, and deepen pre-service teachers' views of inquiry. Teachers' knowledge and skills are practical by nature (Marx et al., 1994); thus, a theoretical approach is neither sufficient nor effective to develop their views of inquiry teaching. To help pre-service teachers enhance their views and practice of inquiry teaching, this study employs two practical approaches: reflective peer teaching practice and teacher educators' feedback on this teaching practice. By introducing pre-service teachers to those approaches, we attempt to understand their views of inquiry teaching and its development through action.

Feedback to facilitate pre-service teachers' reflection and action

The effectiveness of feedback has been widely accepted in teacher education programs. To enhance teacher knowledge, teaching practice and reflection, feedback is often provided by peers, mentor teachers, and university instructors. It is intended as a way of explaining to learners how their work has been evaluated, providing advice on improvement in further actions. Teachers expect students to change and develop

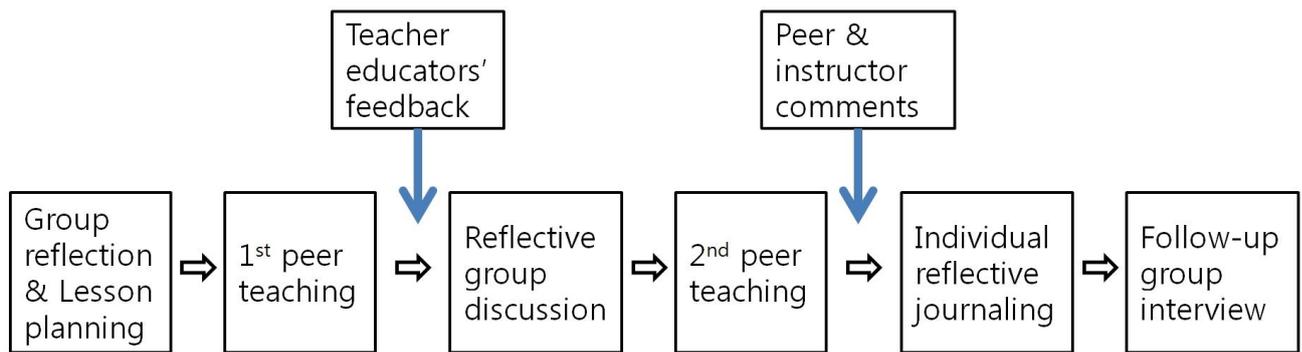


Figure 1. The process of peer teaching and reflection (* Except for individual reflective journaling, each process was done collaboratively in groups.)

their work according to the feedback provided; however, oftentimes processing feedback accompanies a complex cognitive reflection in students' understandings. Students are not passive recipients of feedback; they have their own cognitive schemes to interpret learning situations, and thus they interpret, accept, reject, or ignore feedback based on their own judgment (Pokorny & Pickford, 2010). There are also concerns such as emotions and feelings (e.g., discouragement, de-motivation and incompetence), lack of clarity, the tensions of power relationships between student and instructor, and differences in the expectation of the purpose of feedback. (Bailey & Garner, 2010; Otienoh, 2010). Feedback in higher education is especially dependent on language, mostly in a written format, and thus the meaning or intention of feedback is often too vague and abstract for students to fully understand and adapt (Bailey & Garner, 2010). Thus, providing written feedback on pre-service teachers' teaching practice might not bring forth changes in their understanding, decision making and action as intended. To make the process of feedback effective, a shared purpose and desired outcomes between trainee and trainer and reflective interactions among members are crucial for improvement of performance (Langer, 2011; Pokorny & Pickford, 2010). When there is no consensus of outcomes through communication, the feedback process may yield quite different interpretations and outcomes.

This study employs teacher educators' feedback as a way of developing pre-service teachers' views of and reflection on inquiry teaching. Given that pre-service teachers' views and expectations affect their implementation of inquiry teaching, it is important to look into how they understand inquiry teaching and how they respond to teacher educators' feedback on their teaching. In this regard, this study attempts to understand pre-service teachers' views and actions in relation to teacher educators' views in a teacher education program. Given that there are also differences in pre-service teachers and teacher educators' views of

inquiry teaching as discussed in Demir and Abell's research (2010), we assumed there could be some differences between the two groups participating in this study. When students' understandings and expectations of inquiry teaching are different from teacher educators', it might be difficult to share the purpose and outcomes of performance to improve their teaching. In this regard, their responses toward feedback can be a critical way to delve into what causes conflicts and difficulties in their understanding and practice and how they cope with them. By inviting pre-service teachers into peer teaching and reflective dialogues on feedback, this study attempts to understand and improve pre-service teachers' views and enactment of inquiry teaching. The specific research questions are as follows:

1. *What were pre-service elementary teachers' views of inquiry teaching throughout their reflective peer teaching practice?*
2. *How did pre-service elementary teachers understand and respond to teacher educators' feedback?*
3. *To what extent did pre-service elementary teachers improve their views of inquiry teaching after revising their peer teaching practice based on feedback?*

Through observing pre-service teachers' teaching practice and reflection, researchers in this study strive to look into the complexity of teachers' understandings, teaching practice, and reflection on feedback toward inquiry teaching.

METHODS

Research context

Fifteen elementary pre-service teachers at a university in Korea participated in this study during a teaching methods course, 'Science Inquiry Teaching'. They were in their fourth year in a teacher education program. Before this course, the pre-service teachers completed two science subject matter courses and two science curriculum and instruction courses. Thus it can be said that they had basic understandings of science

teaching before this study. The first author in this paper was the instructor of the course. Before the research started, she explained the research goals and process to the pre-service teachers and they agreed to volunteer for the study.

This study adopts peer teaching practice and collaborative reflection in a science methods course to develop inquiry teaching. During the course, pre-service teachers were engaged in lesson planning, teaching, receiving feedback, revising and teaching, critiquing, and reflecting (see Figure 1).

The instructor encouraged pre-service teachers to form groups of people with similar views of scientific inquiry and interests in science topics. Even though the instructor initiated the grouping, the grouping process was ultimately decided by pre-service teachers. Three groups of 5 (Groups A, B, and C) were formed. Each group discussed what components they needed to include in an inquiry lesson and later chose a topic from the science curriculum and developed a detailed lesson plan. In their lesson plans, they were also asked to discuss and write a group reflection on the following questions:

- *What does it mean to teach science as inquiry? (What are the critical features of inquiry teaching?)*
- *In what aspects do you think your group lesson plan is inquiry-based? (What characteristics of inquiry teaching does your group lesson plan reflect?)*

Each peer teaching lesson lasted 50 minutes. All three groups' lessons were videotaped and saved as a movie (.mov) file format.

Five researchers (teacher educators Y, S, P, M, and J) were involved in this study. All teacher educators work in different universities, teaching science methods courses in teacher education programs in their universities. They have 3-10 years of university teaching and research experience and one of them was the instructor of the course where the study took place. Two of them have 5-7 years of science teaching experience in public elementary schools. The first peer teaching video files, written lesson plans, and group reflection on inquiry teaching were sent to the teacher educators. The teacher educators were asked to write their opinions and feedback based on the following questions.

- *What do you think are the important characteristics of inquiry teaching?*
- *Do you think this given lesson meets the characteristics of inquiry teaching? Explain why or why not.*
- *What would you suggest in order to revise this lesson more toward inquiry teaching?*

The instructor collected all the comments and feedback and gave them to each group of pre-service teachers. Pre-service teachers were asked to individually review teacher educators' feedback as a homework

assignment. During the following class, pre-service teacher groups had their own group discussion for one and a half hours. Each group discussion about teacher educators' feedback was audio-taped and transcribed later for data analysis. The instructor also participated in group discussion. During this discussion, the instructor brought the pre-service teachers' attention to the feedback which teacher educators commonly pointed out. In addition, she facilitated pre-service teachers' reflection by asking probing questions:

- *What were the characteristics of inquiry lesson during your group discussion earlier?*
- *What are the differences between the teacher educators' and your ideas on inquiry teaching? Are there any points raised in their feedback that you had not thought about before?*
- *What do you think are the most important points in their feedback?*
- *If you revised your lesson for a second peer teaching, how would you change it?*

Pre-service teacher groups revised their first peer teaching lesson and finalized their second peer teaching lesson plan on the same topic of the first one. When asking them to revise their first peer teaching lesson, the instructor tried to reduce the authority of experts' comments. She emphasized that pre-service teachers did not need to incorporate teacher educators' comments into their second peer teaching lesson plans unless they agreed, accepted, or understand the comments.

The second peer teaching was processed in the same format as the first one. Pre-service teacher groups implemented their lessons within 50 minutes, and reflective questions and debriefing discussions followed each peer teaching lesson. After the whole process of the second peer teaching practice, pre-service teachers wrote individual reflective journals on their experiences, challenges, and changes in perceptions of inquiry teaching. Two months later, a follow-up group interview was conducted for one and a half hours. Each group of pre-service teachers was asked to reflect on their experiences of peer teaching practices, the helpfulness of teacher educators' feedback, and the in/effectiveness of the course. All group interviews were audio-taped and transcribed for data analysis.

Data analysis

This study involved qualitative data: written data from lesson plans, reflective journals, experts' feedback, observation notes from the instructor, and video and audio data from peer teaching practices, reflective discussions, and follow-up group interviews. In analyzing these qualitative data, we adopted the major phases of data analysis developed by Miles and Huberman (1994): data reduction, data display, and conclusion drawing and verification. Data reduction

involved narrative documents, which we independently created. The narrative documents consisted of specific quotations and lesson segments and incidents; commentary on quotations and lesson segments; and summaries of reflective journals, peer teaching lessons, group discussions, and group interviews. These narrative documents were then placed in three chronological phases: Lesson planning and the first peer teaching practice, reflective group discussion about teacher educators' feedback, and the second peer teaching practice and reflection as well as group interviews.

Guided by research questions, our analysis of narrative documents in each chronological phase focused on pre-service teachers' views of inquiry teaching, their response to teacher educators' feedback, and any changes in their views of inquiry teaching. Narrative documents from multiple data sources were triangulated within each pre-service teacher group to increase the confidence of our interpretation of the data. Several rounds of reading and re-reading narrative documents led to identifying, confirming, and modifying emerging themes to make them logically correspond to the narrative documents. After exploring themes emerging from the data of each pre-service teacher group, a cross-case analysis (Miles & Huberman, 1994) was employed to find commonalities and differences in the three groups. This cross-case analysis helped us to construct an explanation as to how and why one group was different or the same as other groups. In addition, this provided opportunities to re-evaluate emerging themes and evidence from each group by comparing them to other groups, which led to gathering critical evidence to modify the lens of interpretation. Finally, several meetings back and forth were held to discuss our interpretation and framework of analysis after each chronological phase of data analysis, which contributed to the reliability of our interpretation. Several rounds of discussions were necessary to resolve any disagreement and reach a consensus on a framework and emerging themes.

FINDINGS AND DISCUSSION

The findings from three cases indicate that pre-service teachers' views of *inquiry teaching* are intertwined with their views of *scientific inquiry* and *inquiry learning*. We admit that there is no clear borderline to define these three terms. The *National Science Education Standards* (NSES; National Research Council [NRC], 1996) also define inquiry in various ways at the same time (Anderson, 2002). However, it will be practically beneficial to discuss pre-service teachers' views of inquiry teaching in relation to their views of scientific inquiry and inquiry learning. We define *scientific inquiry* as "the diverse ways in which scientists study the natural

world" (NRC, 1996, p. 23), *inquiry teaching* as "pedagogical approaches that model aspects of scientific inquiry" (Deboer, 2004, p.17), and *inquiry learning* as a process of using and revising prior knowledge and constructing new knowledge through the process of inquiry.

Views of inquiry teaching

The first question guiding the present study was regarding pre-service teachers' views of inquiry teaching. The results from pre-service teachers' group reflection, lesson plan, and peer teaching practice reveal three identified themes: *only curiosity and no inquiry question, engaging students in the inquiry process, and doing inquiry solely by students*. These three themes reflect some characteristics of the authentic science that scientists do when they investigate the natural world. So, pre-service teachers viewed inquiry teaching as instructional attempts to involve students in certain steps of doing science. Their teaching practice embraced these themes by starting a lesson with a daily life situation to generate students' curiosity, asking students to predict what would happen, and asking students to conduct an investigation by themselves.

However, the teacher educators in this study viewed all pre-service teachers' peer teaching lessons as not sufficient enough to bring about students' inquiry learning of a target science concept. Few teaching incidents to help students express and refine their ideas about obtained observations were identified. Consequently, a target science concept was delivered in an expository manner at the end of the lesson. Before describing the three emerging themes, an overview of each pre-service teacher group's first peer teaching lesson is described to help the reader understand the teaching context of emerging themes.

Group A (Topic: Heat transfer in liquids, Grade: 4th). In the introduction of the lesson, a pre-service teacher showed students (their peers) the inside of a Styrofoam cup containing instant noodles to evoke students' curiosity about why noodles were located in the middle of the cup instead of at the bottom of the cup. The pre-service teacher said, "Let's find out," and then moved on to main activities by passing investigation worksheets over to students. Students were asked to predict what would happen when a colored ice cube was placed at the top and at the bottom of a cup of hot water, respectively. Groups of students discussed what would happen to the ice cube and drew a picture of their predictions. After sharing their predictions, students then carried out two simple investigations (i.e., placing colored ice cubes in hot water) to test their predictions. They collected data and checked if obtained results corresponded to their predictions. The pre-service teacher provided students with a chance to share what

they found out and then summarized students' investigation results. However, the pre-service teacher did not ask students to reflect on what the results meant in regards to how heat energy transferred between the hot water and cold water from ice cubes. Rather, she immediately started to explain the concept of convection in a didactic manner.

Group B (Topic: A fruit battery, Grade: 5th). A pre-service teacher began a lesson with a daily life scenario in which she was late that morning because her digital clock stopped working. She then asked students how to make the digital clock work without a battery, but with other materials (fruits, soft drinks, metal plates, and wire with alligator clamps). Students were asked to predict what would happen when they put some materials together, and then to come up with a circuit to turn on the clock and check if it worked. Students had multiple chances to come up with a circuit until it worked. Since they did not know much about the principles of the fruit battery, they struggled with choosing proper materials. Students presented their results of which circuits worked and which did not, but many of them failed to make successful circuits despite many trials. The lesson was ended with introducing scientists who also went through lots of trials and errors to discover scientific knowledge, like Volta, who invented the voltaic battery.

Group C (Topic: Balance, Grade: 4th). At the beginning of the lesson, students were asked to help a boy who was trying to get a cookie hanging on a meter stick but the boy was too short to reach it. Afterward, students were encouraged to explore by themselves how to make a balancing mobile with hangers and various weights. At this moment, the only thing done by the teacher was to provide students with materials. No instructional guidance was given to students. Students discussed and wrote down their strategies to balance given materials and presented findings after exploring their strategies. However, the findings were rather too broad and arbitrary for the pre-service teacher's intention and expectation. The pre-service teacher, however, did not address various methods suggested by students much; instead the teacher summarized what she intended to teach and wrapped up the lesson.

Theme 1: Only Curiosity and No Inquiry Question. All three groups of pre-service teachers believed that inquiry starts with individuals' curiosity. This view appropriately captures characteristics of scientific inquiry and an instructionally important feature in inquiry teaching (Hofstein & Lunetta, 2004; NRC, 2000). Pre-service teachers in Group C stated that:

Although children may blow out birthday candles many times, few may have been curious about the smoke coming up after blowing candles out. When a child questions what the smoke is, inquiry begins... (Group reflection, Group C)

However, their peer teaching practice revealed that their view of curiosity was limited to just providing students with an interesting situation. They failed to help students engaged in scientifically oriented questions (NRC, 2000). For example, Group A began their lesson by talking about an instant noodle cup that students might be curious about. However, the lesson suddenly moved on to the main activity in which colored ice cubes were placed in hot water without defining an inquiry question that guided the ice cube activity. Similarly, Group C's lesson started with a possible daily life scenario in which a boy tried to get a cookie hanging on a meter stick. But its aim was to get students' attention and introduce the topic of the lesson. A pre-service teacher then asked students to make a balancing mobile with given materials.

Recent research shows the authentic inquiry practices of scientists are organized around their research question (Brown, Abell, Demir, & Schmidt, 2006; Reiff, Harwood, & Phillipson, 2002). Research on inquiry teaching also indicates that inquiry teaching can be very successful when teachers guide students to interesting questions for them to answer or help them to generate their own questions (Hand, Wallace, & Yang, 2004), and when they facilitate the connection of questions with explanations and evidence (Crawford, Krajcik, & Marx, 1999; Hand et al., 2004). Therefore, inquiry questions are central to inquiry practices of scientists and also students in the classroom. The lack of an inquiry question in any of the three lessons indicates that pre-service teachers possessed insufficient views of scientific inquiry and inquiry teaching.

Theme 2: Engaging Students in the Inquiry Process. Pre-service teachers' views of inquiry teaching in Group A were tied to the process of testing a prediction. During the peer teaching practice, they asked students to predict what would happen and let students conduct an investigation to test if their prediction was right. However, pre-service teachers made no instructional attempts to explore the ideas on which students based their predictions. For example, the pre-service teachers in Group A agreed that the Prediction-Observation-Explanation (POE) process could be the main framework for inquiry and developed a lesson based on this approach. The POE model (White & Gunstone, 1992) was originally developed to uncover individual students' preconceived ideas. During Group A's peer teaching practice, however, no classroom discussion about students' predictions and obtained results was identified. Students just shared what they observed and checked if their predictions were correct. Group B and C were similar to Group A, but more unstructured. The pre-service teachers in both groups asked students to make a prediction and eventually provided students with an opportunity for investigation. They intended to leave students alone to design a fruit battery circuit and make

a balancing mobile, respectively. The pre-service teachers' limited view of scientific inquiry as a process is consistent with previous research findings (Windschitl, Thompson, & Braaten, 2008).

Theme 3: Doing Inquiry Solely by Students. All three groups of pre-service teachers believed that students should carry out an investigation by themselves rather than watching a teacher's demonstration or getting a lecture. Especially, pre-service teachers in Groups B and C regarded inquiry teaching as following a discovery/heuristic approach, which confirms findings from previous studies (Brown et al., 2006; DeBoer, 2004). They seemed to believe that the whole inquiry process can be and should be done by students. Groups B and C stated that:

When students become curious about something, they will be eager to find out how it works. To find out its principle they will contemplate various ideas and then will conduct experiments by themselves to test their ideas... (Group reflection, Group B)

By showing (students) a real life example we help students generate their interest in the topic. Then students will think in diverse ways to solve a given problem by themselves... Namely, children can discover the principle of balance through the process of communicating their thoughts with each other... (Group reflection, Group C)

Interestingly, the pre-service teachers identified inquiry teaching with discovery, thus, they adapted an instructionally "doing-anything" approach during their peer teaching practice. During the peer teaching lesson of Group C students were given materials for a balancing mobile and expected to discover the principle of balance by doing investigations without any further instructional guidance. Similarly, a pre-service teacher in Group B asked students to build a fruit battery circuit with various materials and expected them to figure out successful circuits.

This finding is not surprising at all. The conflation of inquiry teaching and discovery or laissez-faire instruction is common to teachers (Holliday, 2004) and also to scientists who teach in college (Brown et al., 2006).

When we put these three themes together, it is evident that pre-service teachers' views of inquiry teaching are intertwined with their views of scientific inquiry and inquiry learning. First, pre-service teachers portrayed *scientific inquiry* as just a process with certain steps. The reasoning and discursive practices of scientists were not thought to be a central part of scientific inquiry (Sandoval & Reiser, 2004). Second, pre-service teachers' views of *inquiry teaching* reflected their views of scientific inquiry, which prioritized the process of inquiry or leaving students alone with an inquiry activity to let them discover an embedded principle. Facilitating epistemic inquiry practice was not considered during inquiry teaching (Abell, Bryan, &

Anderson, 1998; Chinn & Malhotra, 2002; Howes, 2002). These researchers affirmed that promoting causal reasoning and knowledge-building discourse are central to inquiry teaching. Therefore, these inadequate views of scientific inquiry and inquiry teaching were centered on the lack of adequate views of *inquiry learning*. Pre-service teachers lacked an understanding of how scientists and students refine and develop their knowledge through inquiry. They seemed to assume that students' inquiry learning was guaranteed when they engaged in the process of inquiry.

Pre-service teachers' reaction to teacher educators' feedback

Although pre-service teachers were open-minded to most of the experts' feedback on teaching tips, materials, and activity choices, the analysis of pre-service teachers' group discussion indicates that there was a considerable discrepancy between pre-service teachers and teacher educators in regards to what defines successful inquiry teaching. We identified two types of reactions: ignoring and rejecting comments. Pre-service teachers' ignorance and rejection of teacher educators' feedback was aligned with their own views of scientific inquiry, inquiry teaching, and inquiry learning.

Theme 4: Ignorance. Pre-service teachers in Group A did not take into consideration teacher educators' comments on how to facilitate students' learning of science content. It appeared that they ignored the comments. Teacher educators wanted to encourage pre-service teachers without a negative tone in their feedback. Although they wrote positive notes for following POE steps, they explicitly addressed how to encourage students with cognitive stimulation to effectively promote their learning of science content.

Although Group A adopted the POE model, they didn't seem to understand the rationale behind each phase of the POE model. In the prediction phase, for example, a pre-service teacher asked students to make and share their predictions. No probing questions were followed to explore students' preconceived ideas embedded in their predictions (e.g., Why did you think that way?). In the explanation phase, the pre-service teacher didn't lead any discussion about observed results. She just summarized the results. (Teacher educator B)

However, pre-service teachers seemed to be satisfied with teacher educators' positive comments and exhibited little consideration about how to facilitate effective inquiry learning.

PT (pre-service teacher) 3: *I felt confident when reading we did a good job although there were some mistakes. So I thought in the big picture, our lesson went fine.*

PT 2: *Me too. Professors said overall we followed the POE steps well even though we made many mistakes in details, so I felt our lesson was validated and felt a sense of relief.*

(Reflective group discussion, Group A)

Their discussion about how to revise their second peer teaching lesson was heavily dominated by details about the activity and materials, such as switching the instant noodle problem with another one. Pre-service teachers did not see the main concerns of the feedback as important and just accepted the positive comments.

Theme 5: Rejection. The reactions from Group B and C were more about frustration. Pre-service teachers in Group B were stunned to hear that their lesson coupled with a trial-and-error activity was not effectively enacted because of completely unstructured instruction. Here is one teacher educator's comment on Group B's lesson.

It must be hard for us to expect students to meet what the teacher intends to [in this lesson], unless students are facilitated with the aimed activity where they can think of the problem and the methods... Right now, all materials are prepared on the table but students don't know why those materials are there and they just started to do experiment without any chance to discuss what those materials are for and why they used those materials. (Teacher educator Y)

This was a complete surprise to them. In the group discussion the pre-service teachers conceptually and emotionally struggled with this feedback, given comments as shown in the following conversation.

PT 6: *Our purpose is not telling students scientific principles but teaching them the scientific method of trial and error, so it was not easy for us to accept their criticism... Many experts criticized that there was not a stage for students to make a hypothesis which we could not accept and elementary students could...*

Instructor: *Couldn't you think of the reason why they did? Is this your point?*

PT 6: *Yes, learners at the elementary level cannot think of the reasons why that happened by themselves.*

PT 10: *How can learners at the elementary level make hypotheses if they've never been trained to do so?*

PT 8: *I thought that trial and error is very important. Experts just criticized that the process of trial and error during the lesson looked meaningless. Is 'trial and error' really meaningless? Is it meaningless since it takes time? Does every student need to be successful in trying to do something? These are my questions.*

(Reflective group discussion, Group B)

It should be noted that no teacher educators criticized Group B for not teaching the principle of battery. Rather, they were concerned about the lack of instructional support to help students think of why they did what they did. Similarly, pre-service teachers in Group C strongly explicated their conceptual challenge by refusing teacher educators' feedback. They simply could not agree with the comment that their discovery approach to teaching the concept of balance was not effective and consequently not successful inquiry teaching.

PT 11: *One teacher educator commented that this lesson was designed with the use of discovery learning and said it has much limitation to be considered as an inquiry lesson...*

Instructor: *You cannot understand the point, right? What do you guys think about that?*

PT 14: *Ditto. Why is discovery learning not inquiry?*

PT 12: *One criticized that discovery learning has a limitation to be used in our lesson, but I think that 'discovery' itself is a very basic component in every science lesson. It is students who discover something ... but it has limitation to be used in an inquiry lesson? It doesn't make sense to me. (Reflective group discussion, Group C).*

Pre-service teachers are not passive recipients of feedback; they have their own cognitive schemes to interpret experts' feedback based on their own judgment (Pokorny & Pickford, 2010). Pre-service teachers' reactions to teacher educators' feedback can be interpreted as the outcomes of cognitive conflict (Posner, Strike, Hewson, & Gertzog, 1982). In this case, it was evident that teacher educators' comments on inquiry teaching could not be assimilated into pre-service teachers' existing views of inquiry teaching. In addition, their reactions such as ignoring and rejecting the comments have been identified in research studies on individuals' responses to anomalous data in scientific theories (Chinn & Brewer, 1998; Mason, 2001).

What was then pre-service teachers' pre-conceived view of inquiry teaching that was not compatible with the teacher educators'? As mentioned earlier, pre-service teachers viewed inquiry teaching simply in relation to a process of inquiry or a discovery approach. According to their own views of inquiry teaching, therefore, their peer teaching practice should be evaluated as a fine example of inquiry teaching, regardless of whether students' inquiry learning was effectively promoted or not. Pre-service teachers' different perspectives on their inquiry teaching practice are consistent with the finding from King, Shumow, and Lietz (2001). They reported that in-service elementary teachers often perceive their teaching practice as inquiry-based even though science educators view their lessons as expository. Similarly to those in-service teachers, the pre-service teachers in this study failed to help students grasp a target science concept through doing inquiry and eventually provided expository instruction for a science concept as a discrete event at the end of the lesson.

It should be noted that the impact of inquiry teaching should be evaluated based on its instructional goals. If instructional goals are tied to teaching the nature of science through inquiry, instructional support for students' learning of science content is not a key for determining the success of inquiry teaching. However, if inquiry teaching aims to improve students' learning of a science concept, inquiry teaching practices should be organized around the development of students'

knowledge of the science concept (Chinn & Malhotra, 2002; Crawford, 2000).

Changes in pre-service teachers' views of inquiry teaching

Although pre-service teachers were initially reluctant to accepting teacher educators' feedback, they eventually took the feedback as it was. Since they were required to re-teach their first lesson, they attempted to incorporate teacher educators' feedback into their second peer teaching lesson. The discussion of Group C below shows that the pre-service teachers did not want to give up discovery teaching. But they eventually decided to incorporate the feedback as an alternative choice.

PT 12: *I think it is better for us to provide the problem in a concrete way. We are doing an inquiry lesson, which must not be too open...since we do not have any time left after 40 minutes lesson in an open situation. So it will be better if we offer the problem as a guided one.*

Instructor: *Which means, inquiry should be with open questions and approach if time and conditions permit?*

PT 12: *Yeah [laughing]*

PT 13: *We, anyhow, need to do inquiry teaching during the limited time of 40 minutes? So it will be best if we introduce the (cookie) problem in a concrete and detailed way as long as we aim to meet learning objectives within the given time when students discover and think of something.*

(Reflective group discussion, Group C).

The analysis of the second peer teaching practice, individual reflective journals, and group interview data indicates that pre-service teachers exhibited enhanced inquiry teaching lessons and more adequate views of inquiry teaching. Three themes were identified: *Inquiry teaching as facilitating inquiry learning, inquiry teaching with teacher guidance, and reflection in action.*

Theme 6: Inquiry Teaching as Facilitating Inquiry Learning: Pre-service teachers' lesson incidents indicated that they placed more emphasis on facilitating students' learning through questioning and reflective discussions. Group A helped students engaged in explaining their reasons for their predictions by asking "Why did you think so?" and encouraged them to clarify the preconceived ideas that led to their predictions. Later, the pre-service teacher explicitly requested students to present their results from the investigations and also their interpretation of observed results. Through the whole class debriefing, the pre-service teacher helped students clarify and revise their conceptions of heat transfer by referring to what students observed and why it happened. Unlike a didactic manner at the first peer teaching, the pre-service teacher introduced the new term, convection, when she made sure students interpreted the real world problem (i.e., a bath tub situation) in a similar way to a scientific concept. The second peer teaching lesson was sufficiently elaborated compared to the first one by

placing more emphasis on students' ideas used during the inquiry process (e.g., predicting, interpreting, and concluding) and helping students construct the concept of convection through discussing their observations and interpretations. The pre-service teachers' reflective journals indicated that they changed their view of inquiry teaching from engaging students in the process of inquiry to helping them construct meaning during the inquiry process.

It was not sufficient to say that our first peer teaching lesson was inquiry-based...From the students' point of view our lesson was more about participating in an event rather than engaging in true inquiry. (Individual reflective journal, PT 3)

In the second peer teaching lesson we took teacher educators' comments. By maintaining the phases of the POE model we highlighted "Why?" questions. We also set up a story of filling a bathtub with hot and cold water to give a bath to a baby, in accordance with our instructional topic of 'movement of cold water'...I had a fuzzy view that inquiry is just one teaching model. But this peer teaching project helped me extend my view and be able to see inquiry teaching in various points of view. (Individual reflective journal, PT 4)

Unlike the first peer teaching of Group B and C, no expository instruction, in which a target concept was addressed at the end of lesson as a discrete event, was identified in the second peer teaching lesson. In the lesson by Group B, students explained why their model of an electric circuit would work out, compared working circuits with not working ones, and found out conditions for a closed circuit. Similarly a pre-service teacher in Group C drew out students' pre-conceived ideas by asking them to explain their thoughts about a daily life problem, how to make an unbalanced baby mobile balanced. After various simple activities, a pre-service teacher helped students make conclusions that corresponded to the obtained results.

Theme 7: Inquiry with Teacher Guidance: Laissez-faire instruction was not found in the second peer teaching practice. Pre-service teachers in Groups B and C provided guided forms of investigation. In the lesson by Group B, only one orange and two electrodes (i.e., a piece of copper and zinc) were provided, instead of various fruits, liquids, and metals, along with wires and a digital clock. Students designed a circuit and explained why they thought it would work. More students were successful in designing a closed circuit with the use of given materials and came to easily understand the conditions of an electric circuit. The lesson segments of Group B and their reflective journals afterwards consistently indicated that they realized the importance of teacher guidance in inquiry teaching. One pre-service teacher wrote, "I believed that an inquiry lesson must be done by students only but I realized that inquiry lessons

can be possible with teachers' guidance as well". (Individual reflective journal, PT 10)

Group C intentionally organized main investigations around more structured questions from a conceptually easy one to a more challenging one (make a rod balanced with two 50g weights, 50g and 100g weights, and then 50g and 200g weights) in order to reduce arbitrary results of students' investigations. The lesson done by Group C changed from an unstructured discovery approach to a more guided inquiry approach. The following excerpt shows how pre-service teachers' views of inquiry teaching changed.

I believed that students must do an activity themselves from the beginning to the end to experience scientific inquiry. However, I came to know that students can lose direction when doing too open inquiry, which is not structured, and terminate their activity without any meaningful learning... The critical point for inquiry teaching is for teachers to encourage students to carry out the experimentation voluntarily in the guided situation...(Individual reflective journal, PT 13)

It should be noted that there was no direct evidence to find any change in pre-service teachers' views of scientific inquiry. No change in their views of scientific inquiry after the second peer teaching practice was assumed because there was no discussion or reflection on scientific inquiry after the second peer teaching practice. The analysis of data from the first peer teaching and reflective group discussion indicated that pre-service teachers' inadequate views of scientific inquiry were closely related to their inadequate views of inquiry teaching. Therefore, it seems that pre-service teachers became aware that scientific inquiry in the classroom should be different from scientific inquiry in science, and that teacher's instructional support for students' learning is of critical importance in inquiry teaching (Crawford, 2000).

Theme 8: Reflection in Action: This theme is more about what helped pre-service teachers change their views of inquiry teaching. It was evident that the experience of re-teaching a lesson was a great help in that they could test their revised lesson and eventually experience the success of inquiry teaching. A debriefing discussion right after each peer teaching lesson showed positive peer and instructor comments in regards to facilitating students' learning of science content. The analysis of reflective journals and follow-up interviews revealed the impact of the reflective group discussion and the re-teaching practice on pre-service teachers' internalizing teacher educators' feedback.

Instructor: What if you did not implement the modified inquiry lesson in the second teaching?

PT 7: *The second teaching was necessary. We have never done this kind of training (revising and re-teaching a lesson) before and the criticism from the experts would be nothing without the second teaching. Just feedback itself, nothing else.*

PT 6: *We would just feel good if we received more positive comments from experts and feel bad about negative ones, and that's it. I, however, actively thought about how to improve this lesson on the basis of the experts' feedback since I needed to re-teach it for the second peer teaching. That is, I needed to do modify or add something necessary to make the lesson more inquiry-based with the suggestion of experts' critics since I have to implement it again in the second round! I tried to understand critics and accept their suggestions.*

PT 9: *I learned more about inquiry since I implemented it in class. A theory itself cannot give me learning, but practice with the theory can give me 'meaningful learning' about science inquiry teaching.*

PT 8: *I could not accept experts' comments at the beginning but I came to accept them while I discussed critics with my peers in a group to re-design the second round of the inquiry lesson.* (Follow-up group interview, Group B)

As confirmed in previous studies, reflective discussion played an essential role in students sharing their ideas on inquiry teaching, interpreting the experts' feedback, and guiding future changes in peer teaching (Clandinin & Connelly, 1991; Luttenberg & Bergen, 2008; Mattingly, 1991; Nichols, Tippins, & Wieseman, 1997; Zeichner, 1994). Through reflecting on their own conceptions, views, and actions, pre-service teachers critically question, think, contextualize and reform their understandings and practice (Abell et al., 1998; Daniealowich, 2007; Schön, 1983). Inviting pre-service teachers to engage in collaborative reflection with the instructor was also crucial in this research. Yoon & Kim (2010) showed that collaborative reflection among three parties of educators (pre-service teachers, in-service teachers, and teacher educators) was significant to build a common knowledge base. Without the process of reflective discussion, there might have been abstraction of language in a written format, lack of understanding, misinterpretation and no shared knowledge around the feedback.

The re-teaching practice also played an acute role in developing pre-service teachers' understandings and views of inquiry teaching. It is often said that transformative teacher practitioners reflect on their understandings and in turn, change their action accordingly in terms of reformation of knowledge, curriculum or pedagogy. However, it is also important not to ignore that action can also bring changes in understandings when the understandings are difficult to change. In teacher education, action in the process of reflection needs more attention and needs to be embraced by pre-service teachers. Action has been recognized as one of the key elements in teachers' reflection (Fazio, 2009; Schön, 1987). It is not only the result or outcome of teachers' views or intentions, but also a process and a means of reflection to trigger a transformation of teachers' understandings and views.

IMPLICATIONS

The perspective on inquiry teaching goes beyond just developing process skills such as measurement, the design of experiments, and interpretation of data. It is also a vehicle for knowledge development, so it places an emphasis on using evidence and strategies for developing or revising students' explanations. From this focus of inquiry teaching and learning, students are required to combine their inquiry process skills and science content knowledge while engaging in inquiry activities. And yet, apparently, pre-service teachers do not view developing evidence-based scientific explanations as one of the core practices of scientific inquiry or of inquiry teaching (Driver, Newton, & Osborne, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006; NRC, 2000). They tend to view inquiry teaching as providing students with an opportunity of student-centered investigation or discovery learning. They recognized the significance of evoking curiosity to get students engaged in inquiry learning, and yet, they neither suggested adequate inquiry questions nor encouraged students to think and reason to explain experimental outcomes. Their naïve views and practice on inquiry teaching lack the importance of teachers' facilitation on students' conceptual learning through problem solving.

Without adequate views of scientific inquiry and inquiry teaching, pre-service teachers may not be able to understand why inquiry teaching is crucial to students' conceptual learning of a science concept and also how students' learning process is involved in the process of inquiry. Rather, they may believe that students can easily discover a scientific principle embedded by doing investigations as scientists do. The findings about pre-service teachers' inadequate views of scientific inquiry and inquiry teaching imply that teacher education programs need to help pre-service teachers improve their understanding of epistemic inquiry practices of scientists in science and of students in the classroom.

The positive changes in pre-service teachers' views of inquiry teaching indicate that reflective group discussion and re-teaching a lesson were necessary experiences for enhancing their understanding of how to instructionally support students' epistemic inquiry practices. It appears to be a very challenging task to change pre-service teachers' views solely through written feedback on their peer teaching lessons. Any feedback antithetical to pre-service teachers' views of inquiry teaching might be either ignored or rejected and eventually put away. In addition, if pre-service teachers did not revise and re-teach the same lesson, there would not be an opportunity to incorporate the experts' feedback into their lesson plan and experience the success of inquiry teaching. Thus, reflective discussion alone may not be sufficient to change pre-service

teachers' views of inquiry teaching even though their views can be challenged through such a discussion. This finding implies that reflective discussion and a re-teaching practice are a critical combination to develop teachers' views of inquiry teaching and changes in action.

Inquiry teaching can be a great context to teach inquiry as content (i.e., abilities to do inquiry and understandings about inquiry, NRC, 2000) and the nature of science (Lederman, 2007). However, this study only focused on inquiry teaching aimed to improve students' understanding of science subject matter knowledge. More research studies need to explore the impact of reflective discussion and re-teaching a lesson on teaching inquiry as content and also the nature of science to pre-service teachers.

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