An Analysis of Reflective Thinking of Pre-Service Science Teachers during a Science Methodology Course

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Abstract

In recent years, many studies have argued that reflective thinking helps pre-service teachers to develop expertise in their practice. Teacher's reflective thinking is seen as being helpful in developing teachers into decision makers, thereby helping them to understand their work and define the direction of schooling. Furthermore, reflective thinking is viewed as being able to link theory and practice. Thus, the purpose of this study was to define the types and content of reflective thinking and to measure changes in the types and content of participants' reflective thinking through a science methodology course. In this study, we defined teachers' reflective thinking and analyzed pre-service teachers' reflective thinking demonstrated in their journal writing and interviews. Two pre-service teachers voluntarily participated in this study. The participants took theoretical lessons, demonstrated micro-teaching, and taught students during field experience as part of a three-month long science methodology course and practicum. Reflective practice journals and individual interviews were used for analyzing the changes in and characteristics of pre-service teachers' reflective thinking. The results of this study were as follows. First, the major type of participants' reflective thinking was technical reflection, and much of the content of their reflective thinking leaned toward teaching technique and physical context. Secondly, professional reflection was more appropriate than technical reflection for translating the separated contents into an integrated knowledge set. Thirdly, compared with other periods, pre-service teachers' reflective thinking was dominantly enhanced during field experience.

Key words: Reflective Thinking, Pre-Service Science Teachers, Science Methodology Course

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Ⅰ. Introduction

The importance of teachers in education is emphasized in many research and educational policies in nearly every country. Studies using large databases and multilevel modeling techniques have consistently found that teacher effectiveness influences students' achievement, and is one of the main influences on student progress over time (Muijs & Reynolds, 2002). Rockoff (2004) also reported that teachers are a key factor in improving student achievement.

In Korea, many people have been expressing dissatisfaction with the public education system, discrediting both schools and teachers. To address these problems, many researchers have asserted that the level of teacher expertise is an important factor in improving educational quality (Kwak, 2006; Oh, 2005; So, 2003).

About thirty years ago, the dominant view was that teachers are simply technicians who narrowly construe the nature of the problems they confront, merely carrying out the plans of others; furthermore, educational reform was viewed as a top-down form that involves teachers only as conduits for implementing programs and ideas formulated elsewhere (Zeichner & Liston, 1996). Given this view of teachers, the general teacher education trend was to teach teachers courses in relevant knowledge domains that should become visible in the skills that teachers used in the classroom, but it became clear that teachers did not carry much of this knowledge base into practice and that more was needed (Korthagen, Kessels, Koster, Lagerwerf, & Wubbels, 2001). This teacher education trend was described as Competency-Based Teacher Education (CBTE). The CBTE approach stemming from this technical-rational view was problematic as the knowledge that was produced out of the context to which it was to be applied was not useful in the teaching context (Ghaye & Ghaye, 1998; Shön, 1983).

In 1980, Shulman (1986) turned teacher education toward a focus on the teachers' pedagogical content knowledge (PCK). Shulman (1987) characterized PCK as the particular form of

content knowledge that embodies the aspects of content most germane to its teachability. PCK represented a new, broader perspective of teaching and learning, and concerned the manner in which teachers relate their subject matter knowledge to their pedagogical knowledge and how subject matter knowledge is a part of the process of pedagogical reasoning (Cochran, DeRuiter, & King, 1993).

On the other hand, teacher's reflective thinking was seen as being helpful in developing teachers into decision makers, thereby helping them to understand their work and define the direction of schooling (Pedro, 2005; Valli, 1993; Zeichner & Liston, 1987). Furthermore, reflective thinking was viewed as being able to link theory and practice (Korthagen et al., 2001; Schön , 1983, 1987). Today, almost all professionals in the field seem to agree on the fact that reflective thinking is a generic component of good teaching (Korthagen et al., 2001); reflection leads to views of good teaching being aligned within the notion of reflective practice (Clarke, 1995; Clift, Houston, & Pugach, 1990; Grimmett & Erickson, 1998; Loughran, 1996; Russell & Munby, 1991). Furthermore, many teacher education programs have incorporated strategies to encourage pre-service teachers to think reflectively about their beliefs and practices; many studies claim that reflective thinking helps pre-service teachers to develop their expertise in their practice (Collier, 1999; Korthagen et al., 2001; Lee and Loughran, 2000; Pedro, 2005; Russell and Munby, 1991; Zeichner and Liston, 1987). Hatton & Smith (1995) assert that techniques in fostering a reflective approach need to be provided during initial preparation.

Although several research studies exist concerning strategies to encourage reflective thinking, there is little evidence and consensus about when and what can make pre-service teachers develop reflective thinking since reflective thinking is hard to observe or investigate. In this research, we could find few studies that investigated the degree to which reflective thinking is impacted by science methodology course. The purpose of this study was to identify pre-service teachers' reflective thinking as an expertise emerged during a Science Methodology Course.

Specifically, we tried to redefine reflective thinking based on literature review, to identify the characteristics of pre-service teachers' reflective thinking and to investigate changes in the type and content of their reflective thinking by utilizing two frameworks developed by the authors.

Ⅱ. Theoretical Background

A. Definition of reflective thinking

Dewey (1933) has been acknowledged as the key originator of the concept of reflective thinking (Hatton & Smith, 1995). Dewey (1933) defined reflective thinking as an active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends. Later, the concept of reflective thinking was actively proposed as a means of teacher education by Schön (1983, 1987). Schön (1987) suggested that practitioners use reflection when they encounter situations that are unique, and when individuals may not be able to apply known theories or techniques previously learnt through formal education. Definitions of reflective thinking have somewhat differed among researchers; for example, Boud, Keough, and Walker (1985) took a different perspective from others, defining reflective thinking as a generic term for those intellectual and effective activities in which individuals engage to explore their experiences in order to lead to a new understanding and appreciation. Villar (1995) defined reflective thinking in terms of moves from a stage of uncertainty, doubt, and perplexity, to a goal of mastering the problematic situation or gaining satisfaction when one finds material that will resolve the dilemma.

Dewey (1933) and Boud et al.(1985)'s conception of reflective thinking had emphasized commonly that reflective thinking was concern with prior experiences influencing future experience and learning; on the other hand, Villar (1995) and Schön (1987)'s definitions pointed out that reflective thinking could come from

conflicts and dilemmas.

Based on this literature review, we redefine reflective thinking as a kind of thinking in the process wherein teachers experience and try to resolve the conflict between beliefs / knowledge and the practical experiences obtained through real teaching. Furthermore, we can identify the features of reflective thinking in different ways. Recently, we have categorized the features of reflective thinking into two categories: types of reflective thinking and content of reflective thinking.

B. Type of Reflective Thinking

van Manen (1977) identified three levels of reflective thinking; later, Zeichner and Liston (1987) developed a view of reflective thinking was similar to van Manen's work in laying out a hierarchy of reflective consideration. The first level of reflective thinking identified by van Manen (1977) is technical rationality based upon empirical-analytic paradigm. At the first level, the dominant concern is with efficient means to apply educational knowledge and basic curriculum principles for the purpose of attaining a given end (Korthagen et al., 2001; van Manen, 1977). The second level of reflective thinking is based upon a conception of practical action as hermeneutic-phenomenological paradigm (van Manen, 1977). At the second level, the teacher goes beyond technical rationality and becomes concerned with clarifying the assumptions and predispositions underlying competing practical affairs and assessing the educational consequences toward which an action leads (Zeichner & Liston, 1987). The third level of reflective thinking is critical reflection as critical-dialectical paradigm. Critical reflection incorporates moral and ethical criteria into the discourse about practical action (Zeichner & Liston, 1987). At this level, teachers question the worth of knowledge and the nature of social conditions and criticize dominant institutions and repressive forms of authority to defend justice, equality, and freedom (van Manen, 1997).

Schön (1983, 1987) introduced two different types of

reflective thinking. The first type is "reflection-in-action" and the second type is "reflection-on-action". Reflection-in-action is bounded by the "action-present", the zone of time in which action can still make a different to the situation (Schön, 1983, p. 62). In contrast, reflection-on-action occurs after teachers have been confronted with an unexpected result, perhaps out of the workplace situation (Schön, 1983; Ghaye & Ghaye, 1998).

In this study, we explored pre-service science teachers' reflective thinking using an analysis framework for reflective thinking developed by the authors. This framework was based on three levels of reflective thinking identified by van Manen (1977). In this framework, reflective thinking was divided into three types: technical reflection, professional reflection, and critical reflection (see <Table 1>). The process of reflective thinking exists when a teacher is in a dilemma or conflict stemming from their teaching experience.

The process of reflective thinking is represented as 'thesis-antithesis-synthesis'. 'Thesis' refers to a teacher's preexistent knowledge, beliefs, and practices and 'Antithesis' refers to the external knowledge and context or new knowledge, beliefs, and practices that the teacher considers as alternative. The result of the conflict between 'thesis' and 'antithesis' is a convergence into 'synthesis', which refers to the new knowledge, beliefs, and practices that the teachers themselves decide to be the best-suited alternatives in their teaching practice.

In addition, based on literature review, we can characterize each of three types of reflective thinking. First, technical reflection is the process of constructing new practices and educational knowledge through conflict between the teacher's preexistent educational knowledge/beliefs and teaching practice/context/external knowledge such as theoretical knowledge from universities or academies. In technical reflection, practice is a means to achieve educational goals taken for granted (Grundy, 1987; Grushka, McLeod, & Reynolds, 2005; Kraft, 2002; Killion & Todnem, 1991; Pultorak, 1993). In sum, technical reflection is characterized according to accountability, efficiency and effectiveness in achieving given ends. In addition,

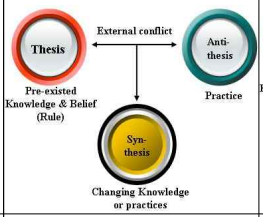
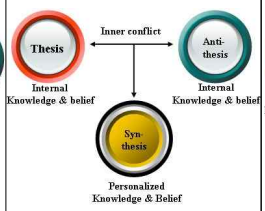
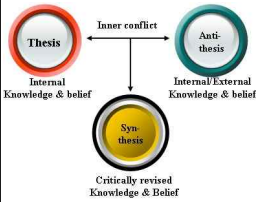
we can present 'focusing questions' to describe questions that encourage reflective thinking when teachers asked them of themselves. For example, "How can I plan lessons in accordance with a curriculum?" is a focusing question in technical reflection.

Secondly, in professional reflection, preexistent knowledge and beliefs conflict with new ones to winnow more educationally valuable approaches when a teacher questions their own knowledge and beliefs and considers more educationally valuable alternatives (Grushka, et al., 2005; Kraft, 2002; Pultorak, 1993, Rearick & Feldman, 1999; van Manen, 1977; Zeichner & Liston, 1987). The most important characteristic of professional reflection is assessing the educational implications and consequences of both actions and beliefs. In the case of professional reflection, we could propose "What is an inherent assumption in this teaching activity?" as a focusing question.

Thirdly, critical reflection considers socio-cultural values as well as educational values in teachers' reflective thinking. In other words, teachers deliberate righteous alternatives when their preexistent socio-cultural-educational knowledge/beliefs/practice conflict with external knowledge/beliefs/practice and/or context. Critical reflection focusing questions are more concerned with approaches toward achieving social justice and human happiness than on educational efficiency (Grundy, 1987; Grushka, et al., 2005; Kraft, 2002; Pultorak, 1993; Rearick & Feldman, 1999; van Manen, 1977; Zeichner & Liston, 1987). An example of focusing question in critical reflection is "Why should I teach it?"

<Table 1> presents the scope of reflective thinking by summarizing processes, characteristics, and focusing questions as types of reflective thinking.

Table 1. Types of Reflective Thinking

	Technical Reflection	Professional Reflection	Critical Reflection
Process	Rule-following action 	Personal frame-(re)making 	Contextual frame-(re)making 
Scope	Educational activities in Classrooms & Schools	Educational aspects in Classrooms and Schools	Socio-cultural-educational aspects in Classrooms, Schools & Society
Characteristics	- Effectiveness for better product - Focus on 'Improving practice' - Assumptions / Goals / Values taken for granted - Reflection according to accountability, efficiency and effectiveness - Instantly deducting results of reflection - Realm is the classroom - External change: Classroom management - Theories are implicit - Theory: Positivism, Technical rationality	- Consideration for more valuable education - Focus on 'Educational knowledge, beliefs, values and assumptions' - Assessing the educational implications and consequences of both actions and beliefs - Knowledge, Beliefs, Values and Assumptions are challenged, conflicted and examined - Internal(self) change: knowledge, beliefs, practice - No implicit knowledge and belief (theories made explicit) - Theory: Constructivism, Interpretivism	- Understanding practice and social context - Focus on social practice and context (social knowledge, belief, value and assumption) - Knowledge, Beliefs, Values and Assumptions of education-science-culture are challenged, conflicted and examined - Science pursuing human happiness and science connected with own life - Greater concern with right and wrong than efficiency - Internal / External change - Theory: Critical Theories
Focusing Questions	- How can I plan lessons in accordance with a curriculum? - Which activities can I choose for efficient and effective lessons? - Did my lesson progress according to plan and was it efficient / effective?	- What inherent assumptions exist in the teaching activity? - Does it (goals, activities, contents, process) have educational value? - What are alternatives for more educationally valuable lessons? - Is my idea the best?	- Why should I teach it? - How can I settle gaps among students', teachers' and societies' demands? - Were these goals / contents / activities connected with student's own life?

C. Content of reflective thinking

When we think reflectively, there is always a content upon which we reflect. What could be the contents of our reflective thinking in education? Novak (1998) proposed that there are five basic components (his word, elements) in education. The five components are learner, teacher, knowledge, context, and evaluation. In addition, Novak (1998) asserted that thinking, feeling, and action are different aspects for looking at educational situation.

Based on these ideas, we have developed a framework for analyzing the contents of reflective thinking (see <Table 2>). As we can see, there are five components pertaining to the elements of education, and three sub-components, which represent the three aspects for looking at education in the <Table 2>. For instance, "Pre/Misconception" is the content related to the cognitive aspects of the learner.

Table 2. Content of Reflective Thinking

Component	Sub-Component	Specific Content
Teacher -Self	Cognitive	1. Content knowledge
		2. General pedagogical knowledge / Pedagogical content knowledge
	Affective	1. Educational Perspectives (Passion / Motivation)
	Practical	1. Type of lesson
		2. Technique of lesson
		3. Attitude as a teacher
Learner	Cognitive	1. Pre/Misconceptions
		2. Cognitive achieving level for learning
		3. Cognition from scientific inquiry and beliefs about subject and learning
	Affective	1. Motivation (interest)
		2. Emotional status
	Practical	1. Main learning method
		2. Behavior in the classroom and lab
Knowledge	Cognitive	1. Content knowledge and concept
		2. Nature of science
		3. Inquiry knowledge
	Affective	1. Value judgments and decision-making
	Practical	1. Procedural knowledge (inquiry ability / activity, lesson activity)
Evaluation	Cognitive	1. Textbook content and concept understanding
		2. Scientific inquiry and thinking
		3. Purpose and methods of assessment
	Affective	1. Value judgments and decision-making
		2. Attitude
	Practical	1. Main learning strategy
		2. Behavior in the classroom and lab, Lab tendency
Context	Cognitive	1. Curriculum
		2. Documents for teaching and learning
	Affective	1. Class mood
	Practical	1. Class size
		2. Student number
		3. Equipment for lab
		4. Time (45-50min)
	External Context	1. Society (Community), Politics, History, Culture, Technology, Other contexts (Climate, Season, Timetable, Job duty etc.)

Ⅲ. Methodology

A. Research Participants

Two pre-service teachers, "John" and "Cathy", participated in this study during a three-month long science methodology course. They initially volunteered after being provided with the purpose of this study by the researcher. After graduation, the participants hoped to become science teachers in physics at the secondary school level. John was a 26-year-old male majoring in physics education with a minor in general science. Cathy was a 23-year-old female majoring in physics education. At the time, these two pre-service teachers were fourth-year students at a college of education in Korea.

John said that a secondary school science teacher needs to consider the student's cognitive levels, adjust science classes according to these levels, and, most of all, needs to love and care for their students. He thought that the conditions of a good science class were that a teacher should interact with the students, considering the students' cognitive levels and interest levels in the lecture, and that the students should be able to express their own opinions in a friendly atmosphere.

On the other hand, Cathy said that the nature of a good secondary school science teacher would be strong understanding of content knowledge and taking the students' cognitive levels into account so that the teacher could help the students to better understand scientific knowledge. In addition, she said that the condition of good science classes is the teacher's awareness of science content knowledge and ability to transmit this knowledge effectively to the students.

B. Data Collection

In the research context, the two participants took a science methodology course that consisted of taking a methodology class in March, demonstrating microteaching in April, and teaching students during field experience at schools in a sequence in

May. Data was collected through a pre-questionnaire and reflective practice journals completed as the participants took a science methodology class on campus in March. At that time, a professor lectured on the theory of secondary science teaching materials. In the second stage, demonstrating microteaching while on campus, the pre-service teachers prepared one lesson from a secondary school science textbook and conducted teaching practice. Each group had four or five members, and the members collaborated on lesson planning and teaching materials. Using these materials, John and Cathy both engaged in practice teaching with the other group members. At that time, reflective practice journals were collected as data at April. During the field experience at May, we conducted individual interviews before and after classes, and analyzed daily field notes, reflective practice journals and a post-questionnaire in May. Data collection was conducted over three month as a period of one semester to enable the researchers to collect data from the two pre-service teachers taking this science methodology course. <Table 3> illustrates the process of collecting the data during the course.

Table 3. Data Collection in the Science Methodology Course

Theoretical Lesson in March	Micro-teaching in April	Field Experience in May
- Pre questionnaire - Reflective practice journals	- Reflective practice journals	- Individual interviews - Daily field notes - Reflective practice journals - Post questionnaire

To identify changes of pre-service science teachers' reflective thinking, we collected data that was composed of reflective practice journals, daily field notes, and individual interviews. The pre and post-questionnaire were to investigate participants' ideas about what constitutes a good secondary science teacher and good science teaching. In their reflective practice journals, pre-service teachers recorded monthly their reflections and opinions about their own experiences and learning during the three-month study period. The pre-service teachers wrote down their daily reflections in daily field notes during their field

experience in May. We observed the participants' lessons (four times for John's class and six times for Cathy's class) and conducted semi-structured interviews before and after the classes. The purpose of the individual interviews was to know what they were teaching to the students and what kind of conflicts they were experiencing, and to identify when and why they changed their teaching practices. The main questions in the interviews were developed based on Danielson (1996)'s reflection sheet and our classroom observations. All the interviews were recorded on a recording machine and transcribed. John was in charge of the 9th-grade class, and Cathy was in charge of the 7th-grade class.

C. Data Analysis

Based on our definition of reflective thinking and its' types and contents, we coded the collected data. Table 1 shows how we coded specific reflections and Table 2 shows how we coded specific content. In order to ensure credibility and minimize researchers' bias, we asked two science education researchers to collaborate in analyzing the data together and compared their observations in order to reach consensual conclusions. We also conducted member-checks where the participants read interview transcriptions and our results to verify our data.

The following were exemplary cases of the three types of reflective thinking:

① *A case of technical reflection:*

"Although I knew that I had to wait for the students' responses, I couldn't put it into practice." (From the Cathy's field notes on May 10)

② *A case of professional reflection:*

"What is the limit of the scope of science content knowledge and concept that I should teach to students? Should I teach students only through showing an experiment or through quantitatively calculations even though the students have

difficulties in understanding?" (From the Cathy's reflective practice journal in April)

③ A case of critical reflection:

"As an option, if students could write about what they can or cannot understand about the subject in their notes, and then if a teacher could check the notes, it would be helpful to the students' learning. The cooperating teacher said that teachers should feel alive when they were teaching. Nevertheless, teachers have to spend much time on administrative tasks. Because of this, they do not have sufficient time to prepare for their classes. Personally, I think that a teacher should not have the duty of performing administrative tasks, mainly because teachers should be spending time on their students instead of on doing such duties." (From an interview with Cathy in May)

This last example is the only case of critical reflection that we found in this study. The participant's conflicts with the external context were expressed in this case.

We extracted content demonstrating reflective thinking and categorized this content through the framework for 'Content of Reflective Thinking' developed in this study. Two researchers participated in analyzing the data. These two researchers analyzed the data together and attempted to reach consensus. Here is an example of how we analyzed the data in this study. This case is drawn from Cathy's reflective thinking.

"After asking a question, I had to wait for a few seconds, but I could not do that." (From an interview with Cathy in May)

In the above case, Cathy experienced conflict between her actual practices and her prior knowledge that a teacher should give sufficient time to students to answer. This contradiction reflectively triggered Cathy's thoughts about the teaching 'question method'. Thus, teaching question method was the 'content' of Cathy's reflective thinking in this case. The teacher's

question method corresponded to the 'Technique of Lesson'. The 'Technique of Lesson' corresponded to the 'Practical' sub-component of teacher-self (see <Table 2>).

Ⅳ. Results

A. Changes in Reflective Thinking According to Terms

1. The type of reflective thinking

<Table 4> shows how the frequency of reflective thinking changed over time. The frequency of John's reflective thinking increases over time. In particular, John's professional reflection just appears through teaching experience from April. His major type of reflective thinking is technical reflection (59%); in contrast, critical reflection is not found at all. Likewise, Cathy's reflective thinking increases over time as well. In particular, we can observe Cathy's professional reflection even in March when there was no teaching experience. Cathy's major type of reflective thinking is also technical reflection (74%); we cannot find critical reflection in her reflective practice journal either.

In addition, <Table 4> shows the relationship between the types of reflection and the number of content included in reflection. For instance, there is a tendency toward professional reflection including greater content than technical reflection. In the case of John, 40% of technical reflection and 71% of professional reflection included more than two content items in the reflection. Similarly, in the case of Cathy, 32% of technical reflection and 60% of professional reflection included more than two content items in the reflection.

Table 4. The Frequency of Reflective Thinking Revealed in the Reflective Practice Journals by Type

Term	March Theoretical Lesson			April Micro-teaching			May Field experience		
Type* / Name	TR	PR	CR	TR	PR	CR	TR	PR	CR
John	2	0	0	1(1)	4(2)	0	7(3)	3(3)	0
Cathy	3(1)	3(1)	0	3(3)	3(3)	0	22(5)	4(2)	0

Note. The number in parenthesis means the frequency of reflective thinking types that include more than two content items.
*TR = Technical Reflection; PR = Professional Reflection; CR = Critical Reflection

2. The content of reflective thinking

<Table 5> shows how the content of reflective thinking changes over time in terms of theoretical lessons, demonstrating micro-teaching and field experience. As can be seen, two of the participants displayed a greater variety of content over time compared to March; nevertheless, the contents of reflective thinking within the 'Knowledge' and 'Evaluation' categories still needed to be developed.

Table 5. The Frequency of Reflective Thinking Revealed in the Reflective Practice Journals by Content

Term	March Theoretical Lesson		April Micro-teaching		May Field Experience	
Participant / Contents	John	Cathy	John	Cathy	John	Cathy
Teacher-self		1	2	6	8	18
Learner	1	4	3	2	8	7
Knowledge			1	4		3
Evaluation						
Context	1	3	2	1	1	6
Total	2	8	8	13	17	34

<Figure 1> displays a dramatic change in reflective thinking content occurring through the influence of field experience. As can be seen, over the three-month study period the frequency of "Teacher-self and Learner" notably increases, whereas the frequency of "Knowledge and Evaluation" does not notably increase.

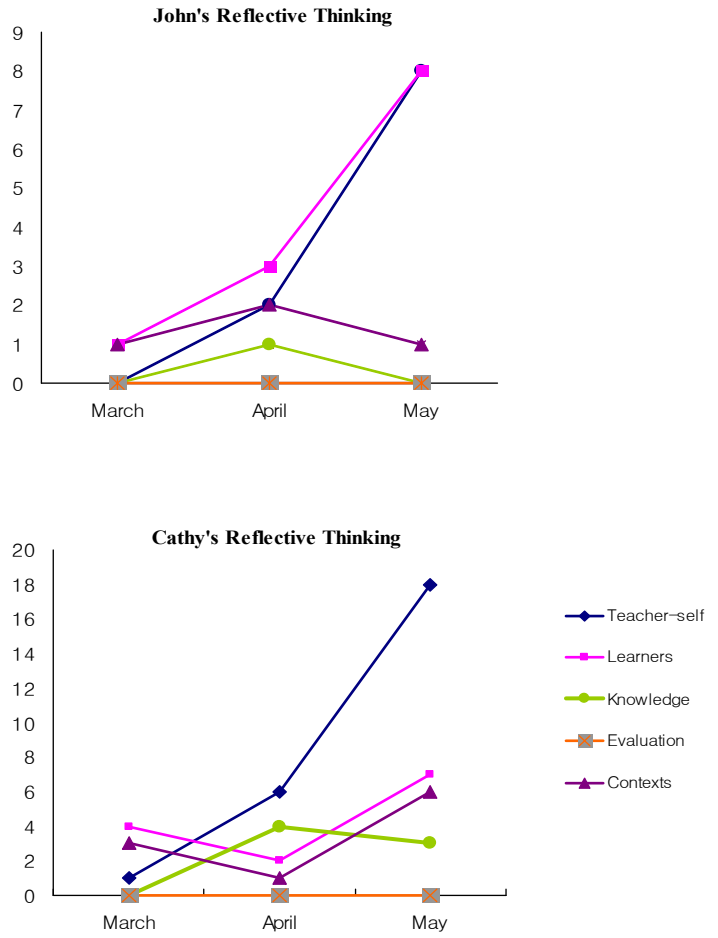


Figure 1. The change in reflective thinking by content

The term "notable content" is used to identify the content that is frequently displayed in the participants' reflective thinking. Content analysis of John's reflective thinking revealed the following content items as being notable: 'Technique of Lesson' within the 'Teacher-self' component, 'Motivation (Interest)' within the 'Learner' component and 'Documents for Teaching and Learning & Class Mood' within the 'Context' component. In contrast, content involving 'Content Knowledge, General Pedagogical Knowledge, Educational Perspectives, and Attitude' within the 'Teacher-self' component, 'Cognition from Scientific Inquiry and Belief about Subject and Learning' within the 'Learner' component, most of the content in the 'Knowledge' and 'Evaluation' component, and content related to socio-cultural perspectives did not appear in John's reflective thinking.

In the case of Cathy, the notable content items revealed were 'Type of Lesson and Technique of Lesson' within the 'Teacher-self' component, 'Cognitive Achieving Level for Learning and Pre/Misconception' within the 'Learner' component, 'Content Knowledge and Concept' within the 'Knowledge' component and even 'Cognitive/Affective/Practical' within the 'Context' component. Similarly to John, the following content items did not appear in Cathy's reflective thinking: 'Content Knowledge and Educational Perspectives' within the 'Teacher-self' component, 'Cognition from Scientific Inquiry and Belief about Subject and Learning' within the 'Learner' component, 'Nature of science, Inquiry knowledge and Value Judgments and Decision-Making' within the 'Knowledge' component, most of content within the 'Evaluation' component and content related to socio-cultural perspectives. Appendix A and B show more detailed results related with their frequencies.

B. In-depth Analysis of Reflective Thinking Occurring during Field Experience

It is important to ask why the dramatic changes in reflective thinking occurred during field experience. To answer this question, we conducted in-depth study of the data from May.

The diverse data sources included the reflective practice journals, the individual interviews, the post-questionnaires, and the daily field notes.

Table 6. The Types and Content of John's and Cathy's Reflective Thinking during Field Experience

Component	Sub -Component	Specific Content	John			Cathy		
			TR	PR	CR	TR	PR	CR
Teacher-Self	Cognitive	1. Content knowledge	1					
		2. General pedagogical knowledge Pedagogical content knowledge				2		
	Affective	1. Educational Perspectives (Passion / Motivation)						
	Practical	1. Type of lesson	3	2		3	5	
		2. Technique of lesson	16	2		15	4	
		3. Attitude as a teacher	2			2	1	
Learner	Cognitive	1. Pre/Misconceptions		1*			1	1*
		2. Cognitive achieving level for learning	4				1	
		3. Cognition from scientific inquiry and beliefs about subject and learning				7	1	
	Affective	1. Motivation (Interest),	9			6	1	
		2. Emotional status	2				1	
	Practical	1. Main learning method	1			1		
		2. Behavior in the classroom and lab	5			3	1	
Knowledge	Cognitive	1. Content knowledge and concept		2*		8	3	
		2. Nature of science						
		3. Inquiry knowledge						
	Affective	1. Value judgments and decision-making						
	Practical	1. Procedural knowledge (inquiry ability / activity, lesson activity)						
Evaluation	Cognitive	1. Textbook content and concept understanding				3		1*
		2. Scientific inquiry and thinking						
		3. Purpose and methods of assessment	1			1	1	
	Affective	1. Value judgments and decision-making						
		2. Attitude						
	Practical	1. Main learning strategy						
		2. Behavior in the classroom and lab, Lab tendency						
Context	Cognitive	1. Curriculum		1		1		
		2. Documents for teaching and learning	2	1		6	2	
	Affective	1. Class mood	1				1	
	Practical	1. Class size	1			1		
		2. Student number						
		3. Equipment for lab	2			2	2	
		4. Time (45-50 min)	4	2		4		
	External Context	1. Society (Community), Politics, History, Culture, Technology, Other contexts						1

Note. * indicates the frequency of reflective thinking types not including concrete content
TR = Technical Reflection; PR = Professional Reflection; CR = Critical Reflection

As a consequence of analyzing the contents of John's reflective thinking in detail, we found that the sub-components

of the 'Teacher-Self', 'Learner', and 'Context' components were more diverse than the others in his reflective thinking. In particular, the notable sub-components in his reflective thinking were 'Type of Lesson and Technique of Lesson' within the 'Teacher-self' component, 'Cognitive Achieving Level for Learning, Motivation (Interest), and Behavior' within the 'Learner' component and 'Documents for Teaching and Learning and Time' within the 'Context' component. On the other hand, the content related to the Teacher's Knowledge and Belief component, the Scientific Inquiry component, almost all of the types of content within the 'Knowledge' and 'Evaluation' component, and the content related to socio-cultural perspectives still needed to be developed.

The analysis results of Cathy indicated that the sub-components of the 'Teacher-Self', 'Learner', and 'Context' component were more varied than the others in her reflective thinking. These results were similar to John's case. In particular, the notable content in her reflective thinking were 'Type of Lesson and Technique of Lesson' within the 'Teacher-self' component. Moreover, we could find almost all sub-components within the 'Learner' component in her reflective thinking. With regard to 'Evaluation', Cathy reflectively thought about 'Textbook Content and Concept Understanding' and 'Purpose and Methods of Assessment'. In addition, Cathy thought reflectively about 'Documents for Teaching and Learning, Equipment for Lab, and Time' within the 'Context' component. Furthermore, the results revealed that Cathy needed to give greater reflective consideration to Teacher's Knowledge and Belief, Scientific Inquiry, and Evaluation.

In summary, John and Cathy showed their reflective thinking more deeply and widely going through the terms; however, the participants' reflective thinking lacked equivalency among the various content types. The participants' reflective thinking inclined toward specific content; for instance, the type and the technique of the lesson, the learners' cognitive achieving level for learning, motivation (interest) and behavior, and the physical circumstances that were used for teaching and learning.

In contrast, there was little content about their knowledge and beliefs, scientific inquiry, the nature of science, value judgments, decision-making and socio-cultural perspectives in their reflective thinking.

Ⅴ. Discussion and Implications

We have refined the concept of reflective thinking based on our literature review. In particular, we composed frameworks for investigating both the types and the content of reflective thinking of science teachers and analyzed pre-service science teachers' reflective thinking using these two tools. In this section, we will discuss the consistency of our findings with previous studies and examine some implications.

Firstly, we found that the major type of participants' reflective thinking was technical reflection. This result corresponds with Thompson and Zeuli (1999)'s finding. As Thompson and Zeuli (1999) described, teachers tend to change their practice in a tinkering manner, picking up new materials and techniques here and there, and incorporating these additions into their existing practice. Technical reflection does not focus on change in a teacher's own knowledge and beliefs, but rather it focuses upon the pursuit of theoretical or preexistent knowledge based upon positivism. In the pre-service teachers' case, their reflective thinking usually involved teaching technique and physical context since their major type of reflective thinking was technical in nature. Comparatively, professional and critical reflection is based upon constructivism and critical theory; thus, established knowledge, beliefs, values and assumptions related to education could be challenged and examined via professional and critical reflection. Accordingly, professional and critical reflection can deal with content like a teacher's own knowledge and beliefs, inquiry and the nature of science, learners' beliefs, value judgments and decision-making. Loughran (2007) and Stoughton (2007) emphasized that teachers need to challenge and explore the taken-for granted and difficult questions in their

practice. These studies indicate the importance of professional and critical reflection as well as technical reflection in teacher education. The developing process of a teacher's knowledge and beliefs is important for achieving growth in the teacher's practice: this development can be stimulated when the teacher engages in professional and critical reflective thinking.

Secondly, professional reflection usually includes a greater range of content than technical reflection. This tendency indicates that, in order to develop professional reflection, we need to connect each type of content together, and then translate the content into an integrated set of knowledge. Shulman (1986) described pedagogical content knowledge (PCK) as knowledge about to how to teach, entailing an intersection of subject matter knowledge and pedagogical knowledge and the consideration of PCK as a primary factor in teacher expertise. Thus, PCK is a type of integrated knowledge. Professional reflection is more appropriate for translating the separated content into an integrated form of knowledge than for translating the content into a technical form of knowledge. Therefore, we need to consider professional reflection as a promising means for enhancing teacher expertise.

Thirdly, we found that reflective thinking becomes more frequent and varied through real teaching practice in a science methodology course. This means that field experience especially teaching experience influenced pre-service teacher's reflective thinking. This finding gives the implication that if a teacher education program could sufficiently provide pre-service teachers with such opportunities, it would have an effect on growth in reflective thinking.

Specifically, John and Cathy stated that the opportunities that helped them the most were the real teaching experience and reflective practice journal writing. In particular, they said that teaching experience helped them to understand the learner's affective and practical considerations as well as cognitive aspects. The field experience provided pre-service teachers with a 'real school world' context so that through these experiences they might begin to address the various pedagogical concerns or

issues that they apprehend in their practice (Lee & Loughran, 2000). In addition, they stated that reflective practice journal writing was very helpful in understanding their practice and in changing their knowledge and beliefs, to consider aspects that they had not previously considered, and to change their plans for the next lesson. Even though most of the participants' reflective thinking has leaned toward technical reflection, teaching experience and reflective practice journal writing were critical factors in enhancing their reflective thinking process. Previous studies have asserted that journal writing helps to bridge the gap between knowledge and action, and to promote reflective thinking (Calderhead, 1991; Pedro, 2005; Surbeck, Han, & Moyer et al., 1991). In addition, journal writing takes teachers through the dilemmas of the profession and helps them to develop a position and a direction for their work (Wibel, 1991).

These findings give rise to a variety of suggestions to science methodology course to help pre-service teachers enhance their reflective thinking. First, science methodology course should links educational theory and teaching practice with regard to learners. Korthagen et al (2001) asserted that teacher education program should emphasize the development of 'Phronesis(perceptual knowledge, practical wisdom)' instead of 'Episteme(conceptual one)' since good teacher is a person of practical wisdom. To address this goal, they suggest that the teacher educator should help pre-service teachers explore and refine their perception through reflection in their concrete experiences.

Secondly, we need to promote reflective thinking of pre-service teachers. To achieve this goal, a journal writing assignment is recommended. Journal writing is a promising method for growth and development to promote their reflective thinking and to assist pre-service teachers to become better thinkers (Wibel, 1991; Smyth, 1992; Surbeck et al., 1991).

Thirdly, the period of teaching practicum and field experience need to be expanded to incorporate sufficient real teaching experience. Working on the improvement of upper secondary education in principle offers students the opportunity

to participate in real-life, meaningful practice (ten Dam and Blom, 2006). In Korea, the period of teaching practicum provided by teacher preparation programs is usually four weeks or sixweeks. In this study context, the period of field experience was only four weeks and the pre-service teachers had six to nine teaching opportunities at the most during the field experience. Furthermore, to guarantee successful field experience it is necessary to establish cooperation among pre-service teacher, universities supervisors, and cooperating teachers at schools (Fallin & Royse, 2000; Wentz, 2001). Future studies need to investigate the effects of the cooperating teacher's roles and a method of guidance to ensure that pre-service teacher enhance the irreflective thinking and receive in-depth teaching experience.

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Appendix A

Table A1. The Changes in John's Reflective Thinking (Types & Content) Revealed in the Reflective Practice Journal

Com -ponent	Sub-Component	Specific Content	March			April			May		
			TR	PR	CR	TR	PR	CR	TR	PR	CR
Teacher-Self	Cognitive	1. Content knowledge									
		2. General pedagogical knowledge Pedagogical content knowledge									
	Affective	1. Educational Perspectives (Passion / Motivation)					1				
	Practical	1. Type of lesson							1	1	
		2. Technique of lesson				1			4	2	
		3. Attitude as a teacher									
Learner	Cognitive	1. Pre/Misconceptions	1								
		2. Cognitive achieving level for learning					2				
		3. Cognition from scientific inquiry and beliefs about subject and learning									
	Affective	1. Motivation (Interest)					1		3	1	
		2. Emotional status									
	Practical	1. Main learning method								2	
		2. Behavior in the classroom and lab							1	1	
Knowledge	Cognitive	1. Content knowledge and concept					1*				
		2. Nature of science									
		3. Inquiry knowledge									
	Affective	1. Value judgments and decision-making									
	Practical	1. Procedural knowledge (inquiry ability / activity, lesson activity)									
Evaluation	Cognitive	1. Textbook content and concept understanding									
		2. Scientific inquiry and thinking									
		3. Purpose and methods of assessment									
	Affective	1. Value judgments and decision-making									
		2. Attitude									
	Practical	1. Main learning strategy									
		2. Behavior in the classroom and lab, Lab tendency									
Context	Cognitive	1. Curriculum									
		2. Documents for teaching and learning				1	1				
	Affective	1. Class mood	1						1		
	Practical	1. Class size									
		2. Student number									
		3. Equipment for lab									
		4. Time (45-50 min)									
	External Context	1. Society(Community), Politics, History, Culture, Technology, Other contexts									

Note. * indicates the frequency of reflective thinking types not including concrete content
TR = Technical Reflection; PR = Professional Reflection; CR = Critical Reflection

Appendix B

Table B1. The Changes in John's Reflective Thinking (Types & Content) Revealed in the Reflective Practice Journal

Com-ponent	Sub-Component	Specific Content	March			April			May		
			TR	PR	CR	TR	PR	CR	TR	PR	CR
Teacher-Self	Cognitive	1. Content knowledge	1								
		2. General pedagogical knowledge Pedagogical content knowledge							1		
	Affective	1. Educational Perspectives (Passion / Motivation)									
	Practical	1. Type of lesson				2	1		2	2	
		2. Technique of lesson				2			10	1	
		3. Attitude as a teacher				1			2		
Learner	Cognitive	1. Pre/Misconceptions	1	1		1				1	
		2. Cognitive achieving level for learning	1				1		3		
		3. Cognition from scientific inquiry and beliefs about subject and learning									
	Affective	1. Motivation (Interest)							2	1	
		2. Emotional status									
	Practical	1. Main learning method		1							
		2. Behavior in the classroom and lab									
Knowledge	Cognitive	1. Content knowledge and concept					2	1*		2	1
		2. Nature of science									
		3. Inquiry knowledge						1			
	Affective	1. Value judgments and decision-making									
	Practical	1. Procedural knowledge (inquiry ability / activity, lesson activity)									
Evaluation	Cognitive	1. Textbook content and concept understanding									
		2. Scientific inquiry and thinking									
		3. Purpose and methods of assessment									
	Affective	1. Value judgments and decision-making									
		2. Attitude									
	Practical	1. Main learning strategy									
		2. Behavior in the classroom and lab, Lab tendency									
Context	Cognitive	1. Curriculum					1		1		
		2. Documents for teaching and learning		1						1	
	Affective	1. Class mood		1						1	
	Practical	1. Class size							1		
		2. Student number	1								
		3. Equipment for lab							1		
		4. Time (45-50 min)							1		
	External Context	1. Society (Community), Politics, History, Culture, Technology, Other contexts									

Note. * indicates the frequency of reflective thinking types not including concrete content
TR = Technical Reflection; PR = Professional Reflection; CR = Critical Reflection

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