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Research on the Characteristics of Science Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK) of Primary School Teachers in Classroom Teaching

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Abstract: The purpose of this research is to investigate characteristics of science content knowledge and pedagogical content knowledge shown in the primary school science classes. Through analysis of classroom teaching, explore the features and differences between primary and secondary school science PCK. Using open-ended interviews with the teachers and group discussions on a regular basis to analyze and compare classes of five primary school teachers, the relationship between CK and PCK. Regardless of the school level the teacher's PCK and professionalism is required with varying focus and emphasis. The features of the primary school teacher's PCK are as follows: Firstly, elementary teach secondary teach content, teachers value pedagogical knowledge (PK) content knowledge (CK). The primary school PCK requires more of understanding of students and teaching methods that to subject areas. PCK be without content knowledge, and the teacher's PCK is subject-specific In addition to the characteristics of PCK in the primary school science teaching, ways to set up professional exchange or collaboration between primary and secondary teachers, and to provide supplementary in-service training focused on content knowledge for primary school teachers.

Keywords: Primary school science, science content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), teacher training

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It is not easy for teachers to change their existing ways of teaching but their efforts of professional development and learning outcomes are driving forces for the change. Recently, the importance of knowledge of ways of teaching certain subjects as well as a firm understanding of content knowledge is recognized. According to previous studies, it is more important to know ways of learning specific concepts and procedures related to subjects than to take more subject-specific content courses (Ingersoll and Kralik, 2004). Subject-specific pedagogical content knowledge (hereafter, PCK) include subject-specific pedagogical methods, basic knowledge about classroom management, subject-specific student assessment, and so on (Lim, 2003; Cho and Ko, 2008).

PCK is translated and used in various expressions that present knowledge about how to teach a specific subject for specific students. PCK represents teachers' unique professionalism that is different from not only content specialists' knowledge of subject areas, but also general pedagogical knowledge (Choe et al., 2008). PCK intends for capturing characteristics of subject-specific teacher knowledge. PCK, therefore, signifies expertise required in teaching specific content. PCK is a core construct defining competitive and professional teachers since PCK is regarded as a key factor for subject teachers' professionalism (Min et al., 2010; Lim, 2003; Magnussoon, et al., 1999; Shulman, 1987).

While the definition of PCK is based on Shulman's definition (Shulman, 1986; 1987), there are subtle differences in the meaning of PCK depending on subjects and researchers. Some characteristics of PCK derived from previous PCK studies in science subject

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are as follows:

First, in science subject area, PCK is recognized as practical knowledge specified in real teaching situations (Hill et al., 2005; Kwak, 2009; Min et al., 2010; Jang and Choi, 2010), and regardless of subject areas, other teacher knowledge areas and context variables that affect subject-specific PCK are suggested. For example, when teachers have profound understandings about subject contents, their instructions can provide various persuasive forms for students with diverse interests and abilities. In order to identify PCK properly, therefore, we need to consider factors that interact with PCK (Ko et al., 2009; Choe et al., 2008).

Eventually, an ultimate goal of PCK is to enhance students' understanding of subject contents. PCK is the teacher's professional efforts to help students successfully reach educational purposes that are proposed in the subject curriculum. In addition, PCK can be represented through the teacher's statements that realize the teacher's ways of teaching (Kwak et al., 2009; Min et al., 2010). Through the teacher's statements, we can understand what is done and why it is done through the practitioner's eyes. Through this understanding we can learn teaching activities better. The teacher's PCK becomes evident by clarifying reasoning and decision making processes on why the teacher applied a certain pedagogy for teaching specific science contents. The teacher's PCK can be identified by making the teacher state what, how and why to teach specific contents in light of students to be taught (Loughran et al., 2004). In summary, sticking to the definition of PCK, PCK is subject-specific teacher professionalism with varying components and surrounding variables depending on subjects, while all researchers share the feature of PCK, that is, representing the teacher's professional efforts to help students reach successfully subject-specific curriculum goals (Cho and Ko, 2008; Choe et al., 2008).

Within this background, in this research we investigated the features of primary teachers' PCK that are differentiated from that of the secondary teachers. Before discussing about the features of primary teachers' PCK, we need to examine whether PCK, subject-specific pedagogical knowledge, exists even in primary school teachers (Cho and Ko, 2008). Regardless of the school level, teachers eventually realize that teaching what they know to students is extremely hard although it's not difficult to learn something for themselves (Choe et al., 2008). That is, understanding something for themselves is entirely different from teaching that to students where PCK is required. Primary school teachers also realize making themselves understood and making students understand are quite different, and they share the existence and necessity of PCK.

Although it is after all obvious that PCK exists regardless of the school level, we can presume PCK realized in the primary school will be quite different from that of subject-specific classes of the secondary school. We need to, therefore, realize that the focus of the PCK can be different between school levels. For example, as such expression as primary school teachers teach children while secondary school teachers teach subject contents (Coke, 2005) suggests primary school teachers are glorified as care givers to children. This shows primary school teachers value pedagogical knowledge (PK, hereafter) than content knowledge (CK, hereafter) in PCK, which is the essence of teacher professionalism. According to previous studies, although CK does not ensure PCK development, PCK can hardly be developed without in-depth understanding of CK (Jang and Choi, 2010; Kwak, 2009; Gess-Newsome, 1999).

In this context, in this research we explored the features of science content knowledge and PCK revealed in primary science teaching. In this research, we investigated the features of CK and PCK in the context of science classes in the primary school while previous research on science PCK has focused on the content-specific PCK in the secondary science classes, That is, we investigated the features of PCK realized in primary school classes, and explored their differences from that of secondary school classes.

Methods

Research on science PCK has been usually conducted on secondary school science classes until now. In the secondary school, the concept and feature of each subject area is clearly distinguished, and subject-specific PCK is distinct since subject specialist teachers teach classes. In this research, we explored the features of PCK of primary school science classes and compared these with PCK of secondary school science classes. To compare PCK of the primary school and the secondary school, we recruited five primary school teachers with varied backgrounds, and videotaped their 2~3 classes after explaining the goals of this research. The five primary school teachers were recruited and selected based on recommendations by other teachers and science educators. Other than random sampling process, these recommended five teachers were interested in this research, and wanted to experience how theories of instructional consulting put into practices based on their graduate studies. This research has some limitations due to these voluntary participants and therefore we need to be cautious not to overgeneralize the result of this study. In addition to the 5 primary school teachers, other teachers and experts also participated in the instructional conferences where all the participants watch and consult about the videotaped classes. The instructional consulting team has conducted various researches including analyzing PCK features of science teaching, developing mentoring programs for science teachers, and so on since 2009. With the expertise and experiences of the instructional consulting team, we could analyze and identify the characteristics of science content knowledge and pedagogical content knowledge shown in the primary school science classes. Table 1 shows the participants of this research.

In addition to instructional conferences, we also conducted in-depth interviews with all participants and discussed about the features of primary school science teaching and primary school teachers' unique professionalism, where we extracted the features of PCK discovered in primary school science teaching.

Table 1. Participants of the research

Group	ID	School level	teaching experience (final degree)
Primary school teachers	A	primary	25 years (Ph.D. candidate)
	B	primary	26 years (M.A.)
	C	primary	4 years (M.A.)
	D	primary	3 years (Ph.D. candidate)
	E	primary	2 years (M.A. candidate)
Instructional consulting team	G	primary	15years (M.A.)
	W	Secondary	18years (M.A.)
	V	Secondary	6years (M.A.)
	Z	Secondary	23years (M.A.)
	X	Secondary	8years (Ph.D.)
	Y	Secondary	14years (Ph.D.)

All the discussions of instructional conferences and personal interviews with the participants were audio-taped and transcribed, which is main data of this research. After videotaping primary school teachers' science teaching, we used those videotapes for instructional conferences, where videotaped classes enabled video-based discussions. In video-based discussions, teachers can talk about and explore what they observed and collected in the video-taped classes (van Esa and Sherinb, 2008), where video-taped classes provides teachers with materials and topics to share in their learning community (Fullan and Hargreaves, 2002). In other words, in instructional conferences teachers begin a conversation with class scenes in the video-taped classes, and examine the problems and solutions through group discussions, which in turn facilitated personal and collective development of the participants. After all, through a conference aiming instructional consulting, teachers can share reflective experiences by conducting collaborative co-inquiry based on the evidence revealed in video-taped classes, where video-taped classes act as catalysts initiating and maintaining conversations (Ko et al., 2009; Choe et al., 2008).

In addition to observational field notes about the videotaped classroom teaching, we used multiple sources of data including transcribed interviews and instructional conferences as well as reviews of the

participants on the analysis result of the instructional consulting team. In this research, we analyzed data on interviews and instructional conferences focused on the difference of PCK between primary and secondary schools. That is, we firstly analyzed the features of primary school teachers' science teaching, and then analyzed ways to improve primary school teachers' science teaching in light of PCK.

Results and Discussion

Based on the results, the features of PCK in primary school science teaching compared with those of secondary school teaching are as follows:

1) Primary school teachers focus on students while secondary school teachers on subject matters

Here are some of the backgrounds that resulted in differences between primary and secondary science classes in light of PCK.

First, in primary schools, basic study skills training as well as teaching subject matters. In primary school, "how to teach children is more important" than teaching subject matters well (Teacher A). Unlike secondary schools, primary schools teach basic study skills training such as "how to write letters, how to write a journal, how to write in a notebook, how to present, and so on" so that children can sit down and study in classes (Teacher C). Studying itself cannot be possible "without these orders and rules" (Teacher D). That is, primary school teachers are differentiated from secondary teachers in that they train immature children so that they can "sit down and study in classes and adapt to orders and rules in a school system" (Teacher C, Teacher E).

A: In primary school classes, we also constantly instruct student guidance and deal with how to sit and write letters, and so on, which is not the case for secondary schools.

C: How to teach children is more important than teaching contents well. Including reading instruction, we also teach how to write, how to split a paragraph, how to grasp a main topic and so on in March at the beginning of a semester. We teach such methods as writing down notes, and so on in detail.

E: In primary school, making children participate in classes are more important. Other than educational contents, children want to play with friends, get attention even in classes, which makes hard to manage classes. So there are all sorts of things for teachers to take care of in primary school classes.

Teacher E said "making children participate in class is more important" in the primary school, insisting on whoever spends a day with primary children as a teacher could not help acknowledging primary school teacher's professionalism. In sum, primary school teachers focus their energy on controlling students' behaviors, and making students pay attention to and participate in class, while secondary school teachers can focus on teaching subject matters without losing their time in getting attention and controlling.

Second, we need to explore primary classes not by subject education, but by the student's development as a whole person. In primary school, the direction of subject teaching is determined in light of children's holistic development rather than the importance of each subject's content education. That is, the status of primary science teaching is determined after considering an overall picture reflecting all classes of subject areas that are integrated and realized. Teacher A explained that after all primary school teachers are like pediatricians who look into "all parts of children" other than orthopedists or chest surgeons who look into a specific part. Like pediatricians, primary school teachers "look into all subjects with children" (Teacher A) while focusing on children (Teacher D).

D: In the primary school, we introduce certain content if it's beneficial to children in light of students' developmental stages and student guidance rather than subject teaching itself or each subject's importance, since there are 13 subjects in primary school. In primary school, we need to consider such aspects as pedagogical methods and children's understanding.

A: It's like doctors' specialties. Pediatricians do not need to examine hearts profoundly with children, although chest surgeons usually examine specific diseases professionally with adults, Teaching many subjects in the primary school doesn't really matter for teachers since each subject doesn't have much content.

Third, in primary school teaching 'learning how to learn' should be more emphasized.

Experienced teachers contended that "knowledge should be taught in accordance with knowledge" if primary schools are to focus on students than subjects (Teacher B, Teacher U, Teacher Z). In a sense, other than secondary schools, primary school is rather the right time to learn how to learn (Teacher Y). That is, "rather than teaching each subject's knowledge structure as omnipotent teachers, teachers should find out what to learn with children starting from examining what they don't know (Teacher Y).

Y: While secondary schools teach knowledge, primary schools teach children, which in turn requires teaching knowledge in accordance with knowledge by taking whys and hows of knowledge itself. In primary schools, teachers should teach children how to study, how to ask questions, how to solve problems, how to critically think, and so on.

W: According to science teaching videos of foreign countries, primary science classes really check and satisfy children's level, including inquiry levels. In foreign science classes, they rarely set the direction of inquiry or conclusion. Teachers guide students step by step by providing students with various inquiry methods or stepping stone knowledge required to progress to the next step, which makes primary school teachers different from secondary school teachers.

Experienced teachers asserted that primary science teaching should reinforce the characteristics of science teaching that is only possible for primary school teaching, where teachers provide students with opportunities to inquire without jumping to a conclusion, adjust inquiry methods and procedures with regard to children's level, and so on (Teacher U, Teacher W).

2) Content knowledge is more emphasized than pedagogical knowledge

Primary school teachers contended that knowledge on pedagogical methods that can be applied to various subjects is more required than high level of content knowledge expertise in primary school PCK. Here are the features of PCK shown in primary science classes where PK is more valued than CK.

First, primary school teachers tend to locate their teaching professionalism in PK.

Primary school teachers in this study argued that PK is critical in primary school teachers' PCK and they have enough CK. If classroom teachers in the primary school figure out the characteristics and levels of children and have active interaction with children, "even teachers with insufficient content knowledge can manage classes well and children will be satisfied" (Teacher Z). If teachers with lack of understanding of content knowledge, however, teach classes, "it is hard to lead children to a higher stage, induce children's higher level thinking, or realize children's critical minds", other than "delivering knowledge more efficiently" (Teacher W, Teacher Z).

Z: It is a mistake to think PK can do everything. Primary school teachers themselves think they have enough content knowledge and PK is critical in PCK, but misconceptions and problems are found in their science teaching to others with profound content knowledge. Teachers' misconceptions and errors in science teaching are caused by the teachers' insufficient content knowledge, where a gap is found between their thinking and reality.

Second, understanding of students is more needed than content knowledge in primary school PCK.

Teacher C emphasized experienced primary school teachers are expected to have "student guidance and character guidance ability", saying primary school teachers need more than knowledge about subject matters and teaching methods. In other words, it is more important for primary school teachers to understand "student guidance, children's developmental states and experiences" rather than professional

literacy in light of subject matters such as science or math (Teacher B).

Teacher A contended that "primary school teachers can attract more children since they understand children", insisting that knowing a lot of science content knowledge doesn't ensure good teaching. Primary school teachers in this study emphasized that teachers should use words comprehensible to students based on their understanding of their student guidance even in communication with students.

A: I couldn't be good at teaching although I knew it well. Teachers can attract more children if they understand students' lives and can provide students with appropriate examples if necessary. When teachers deal with children without preparation, children's understanding of concept also degenerated. Lack of understanding of children's emotional aspects does harm to making children understand content teaching, since children do not understand what teachers say.

B: I think it is hard to teach primary school children for a person with only high-level professional literacy and content knowledge. Primary school needs someone who understands student guidance, developmental state and experiences.

D: There is a teacher that I look after in 20 to 30 years and he has benevolent charisma with his students and classroom management. Even students with troubles or bad attitudes become touched and nice if they go to his classroom. Problem solving ability in various situations is the teacher's expertise.

Furthermore, "lack of understanding of students leads to students' lack of understanding of subject matters" (Teacher A). That is, "lack of understanding of primary students' emotional aspects does harm to their understanding of subject matters", which is resulted from lack of students' understanding of what teachers say in cognitive aspects (Teacher A). In primary school PCK, therefore, "expertise in understanding students" are rather more important than that of subject matter knowledge (Teacher A, Teacher D).

Third, primary school PCK requires teaching methods that can be applied to various subjects, rather than high level content expertise. In primary school, "teaching methods in accordance with children's level" is more important than content knowledge, and furthermore interdisciplinary approaches that can be applied over various subjects are more required than subject-specific PCK (Teacher D).

D: Teachers grappled with how to teach at the children's level can find various teaching methods, which are hardly grasped by learning them. Those ways of teaching ability cannot be improved only with a lot of science knowledge. Those methods can be similarly applied not only to science but also to other subjects such as social studies in primary school.

3) PCK is necessary if a subject is to be taught in accordance with the one

The role of CK in PCK revealed in primary school science teaching is as follows:

First, CK is the foundation for PCK. That is, in a vacuum of content knowledge PCK cannot be expressed. Teachers should use PK based on basic understanding of subject matter knowledge to ensure teaching expertise. Teachers contended that appropriate PK should be displayed based on content knowledge if teachers could use "content-specific teaching methods", which can make students understood what to be taught, rather than using sophisticated teaching methods irrelevant to the content (Teacher W, Teacher Y, Teacher Z).

Y: By the way, how pedagogy can be possible without content understanding? They are not separable (.....) There are too many errors in teaching contents in these classes. Teachers need to correct their own science content knowledge through discussing a lot about their errors and misconceptions with one another. They need to deduce lesson goals from the textbook and curriculum and talk about why the lesson goal is 'knowing air has weight' rather than 'measuring weight', why it is not correct to measure weight in that method, and so on.

Z: This structure is imbalanced since pedagogy is much activated while content knowledge is poor in the primary school. First of all, there is the risk of collapse because of very weak foundations, which

makes it impossible to teach students inquiry or knowledge properly.

Primary school teachers in this study argued that "teachers can reach the lesson goals if they are skilled in PK in spite of somewhat insufficient science content knowledge" since PK is more needed than CK in primary school PCK (Teacher B, Teacher D). Experienced teachers in this study, however, contended that "it is hard to raise students' thinking level or deepen students' understanding of subjects even with excellent PK (Teacher G, Teacher W). In sum, appropriate PK can be possible and meaningful only when it is based on a sound CK. With the teacher's insufficient science content knowledge, therefore, students' possible achievements can be limited although the teacher has excellent teaching methods and techniques (Ko et al. 2009; Choe et al., 2008).

Second, the level of expressed PCK including lesson planning ability can be limited if teachers' science content knowledge is not sufficient (Min et al., 2010; van Driel et al., 2001). Proper PCK cannot be expressed with lack of the teacher's content knowledge. Some primary school teachers said that they "just answer prescribed questions in textbooks without discussing or explaining reasons" when they teach subjects with weak content knowledge (Teacher E). In the primary school, therefore, the quality of subject teaching varies depending on the classroom teacher's disposition, preference, specialty, etc. (Teacher B, Teacher U). Primary teachers deal with some confident subject areas in-depth running out of class time, while dealing with other subject areas as described in the textbook for the lack of their content knowledge (Teacher D). Regarding the depth of content knowledge, teachers "experience lack of class time with too much to talk about" with in-depth subject knowledge, while they waste class hours "spending class hours in classroom management or homework checkout" other than teaching subjects with their insufficient content knowledge (Teacher U). In addition, it is difficult for primary teachers "to prepare all the lessons of too many subjects only to teach once" (Teacher D), which resulted in stark differences in the quality and level of lessons as well as PCK depending on the teacher and the subject (Teacher B, Teacher D).

U: For example, if I am not confident in science, then I usually spend 20 minutes in checking homeworks and finish science lesson in remaining 20 minutes. If I have confidence in the subject, 40 minutes of a class hour is not enough to talk about the content.

B: In primary school, everything depends on the classroom teachers. Teachers with science expertise spend more time in science classes, and some teachers spend more time in writings or other subjects.

D: Sometimes we teach even without looking into textbooks since there are more than 10 subjects in the primary school, It's too difficult to prepare 6 subject lessons if we have six classes tomorrow. Other teachers in my school have advised me that just prepare one or two subjects in a day and teach other subjects by the textbook. Besides, after a couple of rotations, we cannot remember what's in each grade year among the six grades.

Third, primary teachers have difficulty in PCK development with lack of science content knowledge despite their development in PK with more career experiences. Primary teachers contended that once primary teachers are assigned to schools, it is hard to develop proper PCK with rare opportunity to learn content knowledge again including science content knowledge.

Consequently, teachers argued that with more teaching experiences teachers get sophisticated in teaching techniques without deepening science content knowledge (Teacher W). Experienced teachers, however, contended that "teachers need more science content knowledge if they want to upgrade their teaching" (Teacher A, Teacher W). That is, experienced teachers argued that teachers need not only pedagogical knowledge (PK) but also science content knowledge (CK) if primary teachers' teaching professionalism is to be realized (Teacher Z, Teacher D).

Z: We can manage classes if we can control children without good teaching or high-level instructional strategies. We can teach classes by making students memorize English words or solve math problems, and so on, without content foundations. However, teaching is most efficient when teachers use proper pedagogy or teaching strategies, which requires teachers' content expertise.

D: In primary school, teachers with insufficient content knowledge can manage and teach classes if they work in perfect harmony with students and students have a friendly feeling towards teachers. In those classrooms, students as well as teachers with have a high satisfaction level with classes. But that's not good enough.

According to previous studies, the higher the teacher's level of content knowledge, the higher students' achievement (NRC, 2007; Goldhaber and Brewer, 1997; 2000). The influence of the teacher's content knowledge on students' learning varies depending on the school level. As predictable, the level of teachers' content knowledge has more influence on secondary schools than primary schools (Rowan et al., 2002; Hawkins et al, 1998). In addition, according to case studies on science teachers, the teacher's science content knowledge affects classroom practices particularly on classroom discourses (Hashweh, 1987; Sanders et al. 1993). For example, teachers have a difficult time to maintain discussions and deal with students' unanswerable questions when they teach subject areas outside of their major areas (Sanders et al., 1993).

It is necessary, therefore, to prepare measures to reinforce pre-service and in-service teachers' science content knowledge (CK) through teacher (re)education. It is important to note that having content knowledge in a teachable form is more important than having simply in-depth content knowledge. In sum, it is necessary to prepare measures to reinforce subject-specific PCK, that is, a combination of knowledge of basic contents of a certain subject, and knowledge of students and learning of that subject.

Fourth, teachers need to recognize lessons as learning processes with students especially when they teach subjects with lack of their content knowledge.

Primary school teachers are troubled when they don't know how to teach unfamiliar subject content (Teacher C). In this respect, experienced teachers emphasized that teachers should recognize science or math lessons as "learning processes with students using students' natural curiosity", rather than as unteachable and threatening subjects (Teacher B, Teacher W). On the one hand, for the lack of science content expertise it is more necessary for primary school teachers to have students search for answers, where teachers participate in the searching processes as colleagues (Teacher Y, Teacher W). That is, primary school teachers should help students to find answers as facilitators rather than experts when they deal with contents or questions that are beyond their knowledge level. In student-centered, not teacher-centered, classes, the role of teacher is to enable students to ask proper questions and to think about questions rather than to provide right answers to questions. In this context, student-centered, not teacher-centered, means students are taking responsibility for learning for themselves (NRC, 2007).

Experienced teachers advised that primary school teachers feeling lack of content knowledge should try to figure out teaching and learning strategies that support students' learning including "making proper questions, inquiring for themselves, and so on" rather than to improve their expertise in CK of all subject areas (Teacher A, Teacher Y, Teacher Z).

Conclusion

In this study, the features of primary school teachers' science teaching in light of PCK are examined. In light of fruitful and good teaching from a subject-centered point of view, primary school classes are utilizing science or math as materials to teach primary students properly rather than teaching science or math subjects properly. We need to be cautious when we interpret the result of this study since this study investigated the features of primary school teachers' PCK with voluntary teachers who

were willing to connect theory and practice in their teaching. Based on the research results, directions of primary school teachers' PCK development are as follows:

First, it is important to value the transfer between subject areas in primary school PCK. Primary school PCK is highly likely to transfer among subject areas since one teacher teaches all the subject areas. With this transferability among subjects, primary school PCK can be varied by teacher characteristics rather than subject characteristics. That is, the characteristics of primary school PCK are determined by an individual teacher's disposition rather than specific subjects. It can be efficient for primary school teachers to apply PCK across subject areas without being limited to a certain subject area.

Second, the focus of primary school PCK should be varied depending on the primary school student's developmental stages. For example, in the lower grades in the primary school the teacher's PCK can be realized in learning basic literacy such as reading and writing, in the third and fourth grade PCK can be implemented in learning interests or motivations in science, and in the upper grades including secondary schools PCK can be realized in science specialized knowledge or concepts (Choe et al., 2008). Students develop significantly in cognitively and emotionally over the long six years of primary school. Primary school PCK, therefore, has different focuses depending on students' developmental conditions. After all, the aspect of Primary school PCK development should be changed in accordance with the degree of the student's development rather than specific science contents or the characteristics of science content itself.

Third, PCK teacher training programs should be designed in the context of real science teaching in primary schools. Teacher training programs should provide primary school teachers with subject-specific programs. For example, teacher training programs in science need to provide teachers with opportunities to learn science contents, recent studies on students' ways of learning science, ways to teach science, and so on based on science contents that primary school teachers teach in the field. In particular, teacher training programs should be organized focusing on what primary school teachers need to provide for students in the field. That is, the topic of teacher training programs should be organized with a focus on core themes of each subject's curriculum so that primary school teachers grasp how concepts and practices are developed and deployed by each grade (Cho and Ko, 2008).

In this context, it is effective in improving science teaching professionalism to provide primary school teachers with experiences of science activities and inquires (Yi et al., 2007). Through these teacher training programs, teachers are expected to learn key science concepts, ways to participate in scientific inquiry, and ways to implement science teaching and experiences in primary school classrooms based on systematic discussions with colleagues. In sum, teacher learning or professional development should be organized in the real teaching context of science so as to improve science teaching (Choe et al., 2008). It is important to organize teacher training programs that support teachers with constructing practical knowledge in the teacher learning community through reflective practices in light of PCK that is the essence of teacher professionalism (Kwak et al., 2009; Min et al., 2010; Jang and Choi, 2010).

Lastly, primary and secondary schools need to be connected. Primary school teachers are glorified as care givers for children and make and maintain caring relationships with students due to primary school characteristics such as its emphasis on PK rather than CK, and a classroom teacher system where the teacher spend all day with the same group of students (Coke, 2005). On the other hand, the culture of secondary schools are conceptualized as a factory model (Knowles and Brown, 2000) where students should focus on the present lesson putting aside all their previous lessons since different subjects are delivered in each class. Due to this secondary school culture, it is hard to introduce new changes to the school and, most of all, to connect primary and secondary school cultures (Coke, 2005). Separation between primary

and secondary schools in Korea, begun from the pre-service teacher education, delivers an implicit message that they do not need to know each other. This message begun from the pre-service teacher education is transferred to school classrooms by in-service teachers. Primary and secondary schools tend to competitively stand one's own ground and guard one's territory rather than collaborating although they have much to learn from each other with regard to curriculum, theories, practices, and so on.

Primary and secondary schools, however, need to start to share each other's strengths and to discuss about each other's positions. They need to figure out their relationships as connectivity rather than hierarchy, where at first they need to reduce unnecessary gaps and repetitions of content coverage across the grade and school levels (Coke, 2005). Through cooperation between primary and secondary teachers, they need to share and complement each other's strengths to reach common goals, and ultimately increase each other's knowledge base. That is, primary and secondary schools need to cooperate and exchange to construct new knowledge base. Through this exchange, they can decide the scope and sequence of teaching for each grade and school level, and secure feasibility of teaching subject contents (Coke, 2005). Through information exchanges between grades and school levels, the needs of specific areas and students can be better met by reducing unnecessary gaps and repetitions.

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