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THE DEVELOPMENT OF THE KOREAN TEACHING OBSERVATION PROTOCOL (KTOP) FOR IMPROVING SCIENCE TEACHING AND LEARNING

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Abstract. *An observational instrument called the KTOP (Korean Teaching Observation Protocol) was developed to analyze science teaching and to identify the components of teaching that need improvement. To diminish the gap between theory and practice in science teaching, the method for developing the KTOP was structured as consisting of three steps: the first version of the KTOP was developed through direct observation of science classes at the first step, revised through literature review with consideration of the Korean national curriculum and comparison with other observational instruments in the second step, and finalized after application to actual teaching context. As a result, the KTOP was determined to consist of 30 items of 10 sub-categories in 4 main categories. The content was validated through 48 teachers' responses to the questions asking if each indicator of the KTOP is worthwhile to be considered in their teaching. Reliability was obtained by agreement (72~90%) and correlation (r=0.90) among observers' KTOP scores. Finally, the cases of applying the KTOP to improve science classes and to develop teachers' expertise through an in-service program were described.*
Key words: *analysis of science teaching, improving science teaching, observational instrument, teacher's teaching expertise.*

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Introduction

Many science educators have made efforts to develop and implement pre- or in-service teacher programs to improve science teaching and learning (Supovitz & Turner, 2000). However, some educators also have criticized that traditional teacher programs are inadequate and ineffective in improving science teaching and learning in schools (Driel, Beijaard, & Verloop, 2001; Little 1993; Russell, McPherson, & Martin, 2001). For instance, Zeichner and Tabachnick (1981, p. 7) pointed out that the impact of teacher training at the college level is "washed out" when new teachers enter the classroom, and Hobson et al. (2008, p. 113) mentioned that "… many student teachers … (agree with) that they learn more about teaching in schools rather than university classes." Joram and Gabriele (1998) also reported that educational psychology courses at the college level had little impact on pre-service students' views of teaching and learning. For example, in the prerequisite test before taking the educational psychology course, pre-service students responded that learning is "absorbing information" (36%) and "transfer" (23%) but none responded that learning is "change or reorganization of new knowledge." Even after taking the educational psychology course, students still replied that learning is "absorbing information" (28%) and "transfer" (42%). Only 4% answered that learning is "change or reorganization takes place." Smylie (1989) found that among 14 professional development resources, teachers ranked their undergraduate education courses as 13th, and ranked the in-service program provided by their own school districts as 14th.

In an effort to improve teacher learning, science educators have aimed to expose teachers to effective, evidence-based, and up-to-date educational theories and teaching strategies through many teacher-training programs, which encourage teachers to apply what they have learned to their teaching practice. However, if such effective teacher-training programs are not based on and closely connected to everyday practical teaching, these programs will be ineffective in improving teaching practice (Lieberman, 1995; Supovitz & Turner, 2000). According to Putnam & Borko (2000, p. 6), teachers often complain that professional development learning experiences are not in line with everyday teaching situations; as a result, the learning experiences do not have meaningful effects on their teaching practice. This disconnect may be because many teacher programs are too theoretical and abstract (Loughran, Berry, & Mulhall, 2006; Vick, 2006) without detailed consideration of real teaching situations in schools (Driel et al., 2001; Korthagen, 2007; Wallace & Louden, 1992). Wallace and Louden (1992, p. 517) concluded that "The problem… (is) the assumption that teaching is a matter of applying a set of generalizable skills to given situations and that the role of the teacher is to simply choose which skills to apply."

The literature suggests that teacher-training programs should be based on actual science teaching practices, and also should be designed to improve science classes in practice (Guskey, 2003; Hascher, Cocard, & Moser, 2004; Hiebert, Gallimore, & Stigler, 2002; Nielsen, 2012). Guskey (2003, p. 749), based on a review of about 13 lists of the features of effective teacher development, reported that the majority of the lists emphasizes a school-based teacher program. Lieberman (1995, p. 67) noted that "What everyone [teachers] appears to want [are learning experiences]… that engage them in experiencing, creating, and solving *real* problems, using their own experiences." Rogers et al. (2007) also found that many teachers want "classroom application (including classroom resources)" for more effective professional development. In addition, Supovitz and Turner (2000) stressed teacher engagement in concrete teaching tasks as one of the six elements for "high quality professional development."

A more practice training approach is demanded for effective teacher professional development because real teaching is complex and unpredictable (Driel et al., 2001; Hoban, 2005; Korthagen, 2007; Wallace & Louden, 1992). Teaching "is influenced by the interaction of many elements such as the curriculum, the context, and how students respond to instruction…" (Hoban, 2005, p. 9). Therefore, to analyze and improve science teaching, we should observe teaching in classrooms directly and consider the teaching context, including classroom conditions and facilities, students' attitudes, interests and cognitive levels, teachers' teaching experiences, belief and style, and so on.

A single teaching theory or strategy is not guaranteed to be effective in every teaching situation, even though it may have been effective in a specific teaching situation (Trianou, 2007, p. 37). Therefore, ideas for improvement or guidance should be flexible and context-dependent, based on analysis of direct observations of science teaching under investigation. To meet this criterion, researchers have decided to develop a practical and effective instrument to analyze teaching practices for improvement through observation, and to suggest concrete improvement ideas and methods that can be used in everyday teaching situations. The literature indicated the difficulty of developing such an instrument of analyzing and evaluating science classes (Linn, 2000; Tittle & Pape, 1996). Some observational instruments have already been used, such as RTOP (The Reformed Teaching Observation Protocol) designed by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) (Sawada et al., 2002), or OTOP (The Reformed Teaching Observation Protocol) designed by the Evaluation Facilitation Group of the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT) (Wainwright, Flick, & Morrell, 2003).

These tools (RTOP & OTOP) have been used for various goals. For instance, the RTOP can be used to understand the features of science teaching in the classroom and the laboratory. Campbell (2010) used the RTOP to investigate the similarities and differences between Korean and US science classrooms for grades 9-12. The instrument showed no significant differences in the RTOP scores between the two countries, but US teachers showed a higher score than Korean teachers in nine items of the RTOP (e.g., Item 21: "active participation of students was encouraged and valued").

The RTOP is also a useful tool for evaluating the teaching profession and the changes within it. For instance, Akkus and Hand (2011) evaluated the impact of a pedagogical model on mathematics classrooms, and Amerin-Beardsley and Popp (2012) showed the RTOP to be a formative evaluation tool of science and mathematics teachers through peer observation.

Furthermore, RTOP scores can be used to predict students' achievement. For instance, Blanchard et al. (2010) observed that, when applying guided inquiry-based instruction to middle and high school students, students whose teachers had high RTOP scores attained higher scores than other students whose teachers had low RTOP scores, and Jong, Pedulla, Salomon-Fernandez, & Cochran-Smith (2010) reported a statistically significant correlation between students' mathematics test scores and teachers' RTOP scores ($r = 0.56$). Park (2006; 2008) also employed the OTOP tools to profile explicit teaching strategies displayed by experienced teachers in elementary and secondary level in the context of scientific inquiry to realize the commonalities and difference between two groups. Wainwright et al. (2003) also employed OTOP as an assessing tool to analyze instructional practices in standards-based teaching. Flick, Sadri, Morrell, & Wainwright (2009) employed the OTOP instrument to profile faculties' instructional practices to improve their teaching practices in the field of math and science at universities of Oregon.

Likewise, RTOP as well as OTOP can be used for our purpose of improving science classroom teaching. However, as stressed earlier, analysis and improvement effort for science teaching should be context-based. Therefore, we aim to develop a Korean version of teaching observational protocols. The new instrument has been named KTOP (Korean Teaching Observation Protocol) and shares the goals of RTOP and OTOP in its development and employment in researches.

Korea has a national science curriculum that describes the goals, teaching plans, and assessment as well as contents to be learned in each grade from grades 3 to 12. Therefore, Korean science teachers need to consider the national curriculum when teaching science in schools.

In Korea, to become a public science teacher, students who graduate from the college of education for secondary education must pass the national teacher recruitment examination. Because this examination is highly competitive (for example, 12 to 1 in biology, 8 to 1 in physics, 11 to 1 in chemistry, and 7 to 1 in earth science in the year of 2013), marking the examination is very rigorous. Starting in 2014, the national recruitment examination format consists of two steps: 1) the essay test as a type of written test consisting of short answers, descriptive writing as well as a logical one, and 2) actual teaching presentation and interview. All candidates who have earned their teacher certificates and registered for national teacher recruitment examination can take the essay test, which evaluates knowledge in pedagogy as well as science content in the first stage of examination. Then 2 times the number of final teacher recruits at public schools take the 2nd examination, where two kinds of assessments are conducted. In this examination, the first screened teacher candidates show up at their own provinces and take the second examination. In the first assessment, the superintendents or provincial officers of education interview teacher candidates about the teacher image, philosophy of teaching, and personal character as teachers with the same protocols. Teacher candidates are also interviewed to answer what they would do if they were in a situation of educational risk. In the second assessment, the teacher candidates' abilities of developing a lesson plan and demonstrating actual teaching performance are assessed under a given condition. Teacher candidates teaching from their own lesson plan can be evaluated by the observational assessing protocol instrument, in which case we can use KTOP in this practice examination to evaluate actual science teaching performance. Because we aimed to develop an instrumental tool specialized and appropriate for improving science teaching and learning, the KTOP includes particular science-specific features such as "encouraging scientific thinking skills" or "teaching various types of scientific inquiry."

Finally, the efforts by researchers in this study to evaluate and improve science teaching in practice, with consideration of various everyday teaching contexts, do not mean that learning educational theories and effective teaching strategies is unnecessary. Rather, practical improvement of science teaching should be theory-based and research-based (Bednar, Cunningham, Duffy, & Perry, 1995; Hascher et al., 2004; Kearns et al., 2010). Therefore, when developing observational instruments, the research team considered various educational and cognitive theories as well as educational research results. For example, a reliable set of observable teaching practices was considered as an essential factor (Oh et al., 2008; Rosenshine & Stevens, 1986), and the students' abilities of developing argumentation were defined as those of covering purposeful practice involving reflection on how students differentiate theory from evidence and vice versa (Kuhn, 1992, 2007; Park, 2008). The significance of explicit teaching practices in modeling and thinking through argumentation was also emphasized (Kim, Mun, Park, & Lim, 2010; Krajcik et al, 1998; Kwak, 2010; Pressely, Hogan, Wharton-McDonald, Mistretta, & Ettenberger, 1996) as one of the pivotal factors in developing the KTOP.

Research Objectives

Based on the above background, the research objectives are as follows: (1) to develop the KTOP (Korean Teaching Observation Protocol) to detect the parts needed for improvement in actual science teaching in the classroom or laboratory, (2) to describe the basic goals, the process of development, and validity and reliability of the KTOP, and (3) to introduce the some applications of the KTOP.

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Development of the KTOP

Basic Goal and Components of the KTOP

The basic purpose of the KTOP is to use it to improve science classes by observing the science classes directly and analyzing areas for improvement. To this end, the KTOP includes counter-examples of areas of improvement and examples of actual improved teaching situations (Table 1). All counter-examples and examples for each item of the KTOP were collected from actual observations of science classes and from efforts for improving science classes through researcher-teacher cooperation. More detailed explanations of how to use the KTOP for improving science classes will be given in the later section, "Application of the KTOP: Applying to POCOM (Practical On-Site Cooperation Model).

Table 1. An instance of a KTOP item consisting of four components.

KTOP item	Students are on task actively in class
Operational definition	- There are activities, presentation, discussion and games in groups where students construct and exchange their opinions rather than passively listening to teachers' lectures.
Counter-examples	- The lesson consists of teacher-centered lectures during which students copy notes from the board or provide simple answers. - There is group work, but only a few students lead the activity or lessons, and others participate passively.
Examples	- Teacher makes students think about the core concept and show related phenomenon. Then, students write the observations on activity sheets and compare them with peers in groups. - A teacher explains why such a phenomenon happened instead of presenting a direct explanation. Students exchange opinions with peers in groups and answer the teacher's questions.

Developing Process of the KTOP

To develop an observational tool which can be used to identify the aspects of improvement for better science teaching, the 'direct observation method' (Dragnidis & Mentzas, 2006; Parry, 1996) and the 'generic model overlay method' (Dubois, 1993) were applied. These methods have been used to identify components of competency required to perform and complete a given mission or task in more successful and effective ways in the areas of management, psychology, education, and so on.

The 'direct observation method' can be used to extract and code characteristic behaviors when observation subjects perform a given task, and to generate a tentative list of competencies. For instance, Draganidis and Mentzas (2006, p. 56) noted that, "A competency model is a list of competencies which are derived from observing satisfactory or exceptional employee performance for a specific occupation." In this study, direct observation of science teaching in everyday context was conducted to generate the first version of the KTOP. This method was used because, as noted in the introduction section, many educators have emphasized that improving teachers' expertise or actual teaching in the classroom should be based on everyday teaching situation considering the teachers' teaching attitude or habit, students' interest or cognitive level, classroom atmosphere, and so on (e.g., Hascher et al., 2004; Hoban, 2005; Putnam & Borko, 2000; Korthagen 2007).

"Isolating the characteristics of exemplary performers is achieved by observing them… competencies characteristic of exemplary performers only become the basis for complete competency model development." (Rothwell & Lindholm, 1999, p. 98). This means that the initial model needs revision. Therefore, we adopted the 'generic model overlay method', in which the prior existing model is revised through various processes, such as comparison with other models, consideration of the developer's own goals, and so on. In this study, the first version of the KTOP was revised based on literature review, analysis of the Korean national science curriculum, and comparison with existing other observational tools (RTOP and OTOP). This is because 'practice should be based on the theory' as stressed by many educators (e.g., Bednar et al., 1995; Kearns et al., 2010; Hascher et al., 2004)

Using these two approaches, it is expected that the gap between theory and practice can be minimized. Finally, the KTOP was confirmed and revised again by applying it to actual science teaching to increase its concreteness and feasibility.

As a result, our developmental method for the KTOP can be structured as shown in Figure 1, consisting of three steps: bottom-up approach, top-down approach and field test.

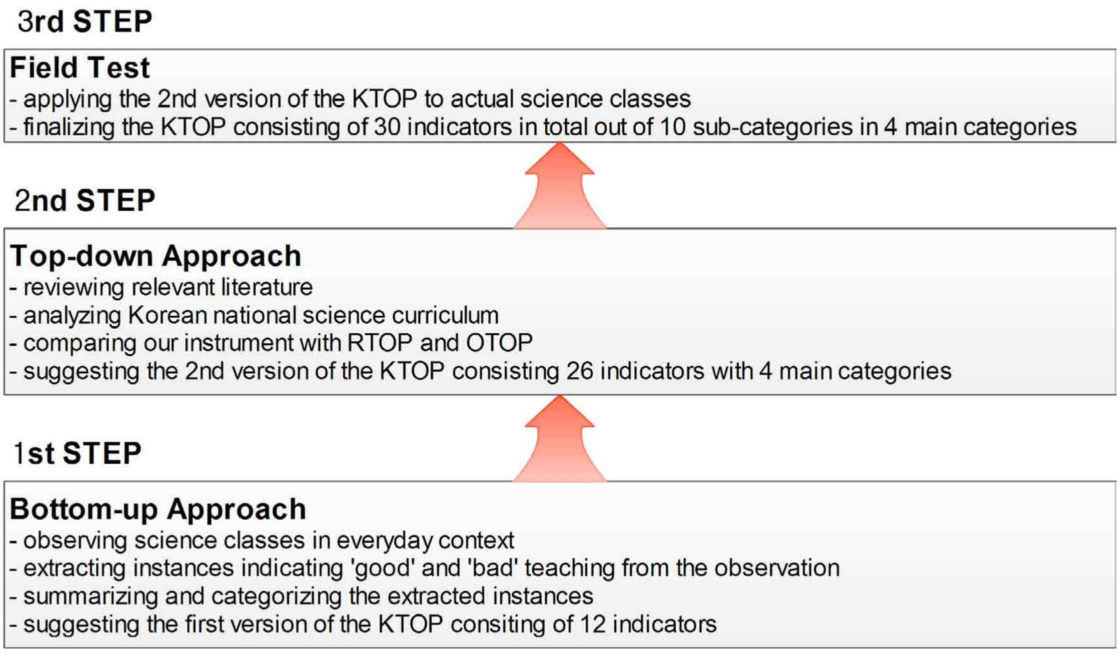

Figure1: Developmental process of the KTOP through 3 steps.

First step

In the bottom-up approach, we (professionals and experts in science education) observed a science class in everyday context, and discussed the parts that needed improvement with an open mind, that is, without any pre-determined observational tool. As professional science educators, we teach college students in pre-service courses at the university; develop and implement in-service programs to develop teachers' expertise and to help science teachers' actual teaching in schools; participate in reforming the national science curriculum; and publish science text books. And we also have experience teaching science at the junior or secondary high school level, as science teachers before working as science educators at the university. Therefore, we have intuition, practical experience, and professional expertise on what good science teaching is in schools.

After observation of two typical science classes (earth science classroom and chemistry laboratory teaching), for the aspects of improvement in science teaching and learning were determined. Through this process, instances that indicated "good" or "to be improved" science teaching and learning were extracted as shown in Table 2.

Table 2. Summary of features of the observed science classes using the bottom-up approach.

Category		Observation	Area to be improved or good indicator
The overall direction/ philosophy of learning	Main features of whole process	- Teacher read and explained textbook, told students to underline parts of the text and asked questions requiring short/exact answers. Finally, teacher summarized the main content on the blackboard.	- Teacher needs to consider constructivist teaching and learning
		- Teaching consisted of providing and explaining separate scientific concepts and information.	- Teacher needs to provide a coherent explanation based on theory, model, or big idea.

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Category		Observation	Area to be improved or good indicator
Cognition of learning	Meta -cognitive awareness	- Teacher checked what students learned and knew. - A teacher encouraged students to consider how/why questions while conducting experiments.	- Good indicator - Good indicator
Teacher's PCK	Practices for explaining	- Teacher confuses the relationship between the theory and evidence. That is, he/she used the theory instead of evidence supporting natural phenomena. - Teacher failed to help students change their misconception identified in the teaching. - Teacher sometimes taught science concepts wrongly or incompletely, or skipped important concepts. - Teacher missed the link between big ideas and small concepts.	- Teacher needs to understand the NOS (e.g., difference between theory and evidence). - Teacher needs to consider a conceptual change model. - Teacher needs to understand scientific concepts thoroughly. - Teacher needs to link small concepts with big ideas.
Learning practices	Students' behavior /practices	- There were no student-centered activities except answering short answers, reading the textbook, and underlining phrases in the textbook. - In the final step of the lesson, students summarized what they learned using a simple but interesting game.	- Teacher needs to encourage students to participate in their own learning through various activities. - Good indicator
	Teacher's teaching strategy	- There were no specific teaching strategies except asking questions, reading from the book, and underlining important phrases in the book. - Teacher elicited mainly closed answers.	- When reading the textbook, the teacher needs to use a variety of reading and summarizing strategies. - Teacher needs to use open questions (for creativity).
	Interaction between teacher and students or among students	- The only interaction was asking and answering the questions. - Teacher ignored students' unexpected questions and responses.	- Teacher needs to encourage students to think, present, compare, and discuss their own ideas. - Teacher should deal effectively with students' various responses.
	Inquiry activity	- Students did not carry out the activities to develop various inquiry skills*. - Teacher did not use appropriate demonstrations.	- Teacher needs to include "to differentiate," "to interpret the data" or "to think inductively" as teaching goals. - Interesting demonstration is preferred.
Assessment	Assessing students' learning	- Teacher gave score to students who answered the questions, and the teacher tried to give all students the opportunity to answer the questions.	- Good indicator for formative assessment and active participation.

**Inquiry skills in KTOP include those of integrated process skills as well as basic one in SAPA (Science: A Process Approach) (Turpin & Cage, 2004).*

The "good indicators" in the last column of the Table 2 needs to be continually encouraged and the "to be improved" aspects need to be considered for improving science classes. As a result, based on Table 2, the following 12 items were determined as basic components of the first version of the KTOP.

1. Constructivist teaching and learning need to be encouraged.
2. Various connections between small concepts and big idea, theory and evidence and so on are important.
3. Metacognitive awareness during classroom learning and experiments is necessary.
4. Teaching and learning science should be based on correct NOS understanding.
5. Considering students' misconceptions and the change of them are required.
6. Correct understanding and exact explanation of scientific concepts are essential.
7. Various teaching strategies to encourage students' active participation are necessary.
8. Various learning activities, including games, demonstrations, and so on, are important to improve students' interest, motivation or active participation.
9. Open questions are recommended to develop scientific thinking skills or creativity.

10. Presenting, comparing, and discussing students' own ideas, as well as asking and answering the questions, are important for active communication.
11. Various types of inquiry activities (inductive, deductive, and abductive) that require various types of inquiry skills (integrated as well as basic process skills in SAPA) are recommended.
12. Appropriate and effective assessment is necessary.

Among the above items, some items can be extended for further comprehensiveness: for instance, the second item can include other connections such as the link between scientific concepts and everyday experience or the link between today's learning concepts and students' prior knowledge. The initial item can be subdivided even further; for instance, the eighth item can be divided into activity for interest/motivation and activity for students' participation. This process was conducted using the following approaches.

Second step

The second step, that is, the top-down approach, revises the first version of the KTOP. First, we reviewed the science education literature about the basic philosophy and fundamental goals of science teaching and learning, and various teaching elements or conditions including teaching strategies, learning activities, assessment tools, and so on. Table 3 indicates a brief description of the literature review that was done to obtain the theoretical background for developing the KTOP.

Table 3. Features stressed in the literature for "better" teaching.

Source	Features
Abrams (1998), Çimer (2007), Porter and Brophy (1988)	For effective teaching, they stressed (1) students' existing ideas and conceptions, (2) application of new concepts or skills to new contexts, (3) students' active participation in lessons, (4) inquiry and cooperative learning, and (5) continuous assessment with feedback.
Burry-Stock (1995)	He developed a rubric for constructivist teaching and learning, consisting of 4 categories and 18 items. The four categories are (1) learning from a constructivist perspective, (2) pedagogy related to student understanding, (3) strategies based on interactions with students, and (4) teacher knowledge of subject matter.
NRC (1996)	It stresses a shift from traditional pedagogy to more reformed one. It describes which aspects need to be 'less emphasized (e.g., learning science by lecture and reading)' and which aspects need to be 'more emphasized (e.g., collegial and collaborative learning)'.
Supovitz and Turner (2000)	They emphasized (1) concrete experience before introducing an abstract concept, (2) connection of science with other disciplines, (3) use of computers, (4) various types of questions to evaluate students' understanding, (5) inquiry activity in groups, and (6) development of conceptual understanding.
Weiss, Banilower, Crawford, and Overstreet (2003)	They suggested sample indicators for assessing the quality of the lesson, consisting 4 categories with 21 items. The four categories are (1) design of lesson (e.g., design encouraging a collaborative approach), (2) implementation (e.g., adjusting instruction according to students' level of understanding), (3) science content (e.g., accurate content information, and connection of science to other disciplines), and (4) classroom culture (e.g., active participation of all students).
Tigellar, Dolmas, Wolfhagen, and van der Vleuten (2004)	For teaching competencies in higher education, they identified 61 items (e.g., a teacher can activate students, assess students' learning results, and so on) categorized into 7 domains (e.g., expert on content knowledge, facilitator of learning processes as an evaluator, and so on).
Schraw, Crippen, and Hartley (2006)	For constructivist-oriented instruction in the classroom, they stressed (1) inquiry based learning, (2) collaborative support, (3) improvement of problem-solving and critical thinking, (4) support to help students to construct mental models and experience conceptual change, (5) use of technology, and (6) impact of students' and teachers' beliefs.
Kim et al. (2010), Oh et al. (2008)	They stressed the teacher's expertise in (2) organizing science content, (2) evaluating students' understanding, (3) demonstrating appropriate PCK, and (4) preparing materials appropriate to students' levels.
MCEECDYA (2010)	They provided a standard for professional teaching consisting of 3 domains; professional knowledge, professional practice, and professional engagement. Among them, professional practice, which relates to our concern, specifically, consists of 3 categories with 18 items.

As mentioned, the areas needing improvement should adhere to the standards of teaching and learning science described in the science curriculum. According to the Korean national science curriculum, as well as the concepts and inquiry activities to be taught, the strategies of teaching and learning science are described as follows: how to plan lessons, what materials to prepare and how to use them, how to teach, how to guide experimentation, how to support teaching and learning, and lastly how to evaluate learning related to science. Therefore, when revising the KTOP, we considered how we could help science teachers equip themselves with professional strategies of teaching and learning science as described in the Korean national science curriculum.

In the second step, the RTOP and the OTOP were also considered to revise the first version of the KTOP. The RTOP consists of 25-item classroom observation protocols for "reformed" teaching, emphasizing (a) standards based; (b) inquiry-oriented; and (c) student-centered teaching and learning (Sawada et al., 2002). The OTOP consists of ten categories of concrete and measurable teachers' practices, along with students' responses (Wainwright et al., 2003).

In RTOP, some items cannot be measured as explicit teaching practices. For example, one item of teaching, "teacher had a solid grasp of the subject matter content in the lesson" from RTOP, is not explicit in measuring how much the teacher conveys the concept appropriately or accurately, because "knowing" is different from "teaching."

In the comparison of the RTOP with OTOP, it was found that the OTOP consists of ten categories of concrete and measurable teachers' practices with students' responses, unlike the RTOP, where only teachers' teaching strategies are indicated. Therefore, we determined that the students' activities or responses, as well as teachers' practices, needed to be encouraged in the KTOP.

Comparing the observation of actual science teaching (in the bottom-up approach) and literature review (in the top-down approach) with the RTOP and OTOP, it was found that the following characteristics were excluded in the RTOP and the OTOP;

1. Teaching the nature of science;
2. Implementing various types of inquiry activities (inductive, deductive, or abductive inauiry) as well as a confirmation activity;
3. Checking the preparation and clean-up of the lab materials, in addition to lab safety;
4. Promoting students' interest/motivation in their learning; and
5. Employing appropriate assessments of students' learning.

Finally, to make the KTOP a tool explicitly specialized for science teaching and learning, rather than for teaching and learning of all subjects like the RTOP and the OTOP, we added the following statement: "Students understand the inquiry process meta-cognitively rather than blindly follow a procedure," Here, an inquiry skill or process through inquiry activities refer to those of inquiry processes defined in SAPA, consisting integrated inquiry processes as well as basic ones as defined in Table 2. "Teacher encourages students to develop or employ scientific thinking (deductive, inductive, and abductive thinking) during the class" or "Students apply what they learned to various contexts (daily life, engineering/technology or environmental situations)."

Through this top-down process (literature review and consideration of the Korean national science curriculum and the RTOP and the OTOP), the initial 12 items are revised into 26 items with 4 main categories (philosophy, learning goals, activities and assessment) and 10 sub-categories (constructivism, the nature of science, conceptual understanding, inquiry, development of thinking, interest and motivation, connection, teaching strategies and materials, cooperation and communication, assessment).

Third step

In the third step, the revised version of the KTOP was applied to actual science teaching in a field test for validation. Here, we checked whether we could profile teachers' and students' practices of science teaching and learning easily by using the indicators from the KTOP. For example, in a chemistry lab class, we could easily observe students'participation in a teacher's demonstration of a flame reaction with different chemical materials; however, we were not sure if students were on task; that is, it was difficult to interpret whether students were participating in their learning even though students were watching a teacher's demonstration. If students had been interacting with the teacher through questions and answers during the demonstration, then we could have interpreted their participation as active learning. Therefore, the term of "participation" was revised to "on-task" to indicate that participation must be active, not passive.

In another example of a chemistry lab class, more definitions were added to describe what could be observed during the lab class. For example, it was found that teachers needed to check students' prior inquiry skills before conducting the inquiry, and to encourage students to compare the results with hypothesis or prediction in the final step of the experiment.

In a physics classroom, it was observed that the teacher introduced various characteristics of "light" only verbally. In this case, it was confirmed that using materials or demonstrations is essential to making abstract concepts concrete.

As a result, after the revision through the field test, we determine 30 items of four main categories (philosophy, learning objective, practices, and assessment) and ten sub-categories, as shown in Table 4. Here, the prior five categories (Table 2) were reduced into four: philosophy, goals of learning, activities, and assessment. The prior categories of goal of learning and goal of teaching in Table 2 were combined into one, learning objective, in Table 4.

Table 4. KTOP (Korean Teaching Observation Protocol).

Category		Item
Philosophy	1. Constructivism	1.1 Students are on task actively in class.
		1.2 Students realize the objectives and products of class activities metacognitively.
		1.3 Teacher, as a supporter, facilitates students' learning, not directs it.
Goals of learning	2. Nature of Science	2.1 Teacher helped students understand the nature of science.
	3. Concept Understanding	3.1 Teacher encourages students to reflect on their prior knowledge, and employs conceptual change model if there was any misconception.
		3.2 Teacher explains core concepts appropriately and accurately.
		3.3 Teachers make difficult and abstract concept (including graphs, code, symbol, etc.) more understandable and easy.
		3.4 Students model and construct their own understanding through active exploration and inference activities.
		3.5 Students reflect on their own or other students' understanding, metacognitively.
		3.6 Students extend their basic understanding about concepts to a more complicated and wider scope.
	4. Scientific Inquiry	4.1 All materials are prepared before lab activity and students clean up after lab activity.
		4.2 Teacher provides lab safety instructions to students before and during experimentation.
		4.3 Teacher checks students' existing inquiry skills and provides appropriate instruction for revising them if necessary.
		4.4 Students realize the inquiry process meta-cognitively rather than blindly follow a procedure.
		4.5 Teacher instructs students to develop inquiry skills in more detail if necessary, such as skills of observation, variables control, or hypothesizing.
		4.6 Students evaluate the experimental results by comparing them with the hypothesis and inferring reasons for errors.
		4.7 Students carry out various types of inquiry activities, such as inductive or hypothesis-deductive activities.
	5. Scientific Thinking Development	5.1 Teacher encourages students to develop or employ scientific thinking (deductive, inductive, and abductive thinking) in class.
		5.2 Students have a chance to develop their claims by discussion or argumentation with supporting evidence.
		5.3 Teacher encourages creative thinking through various activities.
	6. Motivation and Interest	6.1 Teacher motivates/interests students in their learning.

Category		Item
Activities	7. Connection	7.1 Teacher integrates content with other classes or interdisciplinary curricula.
		7.2 Students apply what they learned to various contexts (daily life, engineering/technology, or environmental situation).
	8. Learning Strategies/ Tools	8.1 Students use various learning strategies such as analogy, concept mapping, and so on.
		8.2 Various appropriate media such as computer, graphics, drawings, video, demonstration, and so on are used.
		8.3 Students participate actively in various learning activities such as worksheet activities, games or role plays.
	9. Cooperation and Communication	9.1 Teacher encourages students to be cooperative in learning through group activities.
		9.2 Students communicate with teachers or with one another through discussion and presentation.
		9.3 Students ask and answer questions actively, and the teacher responds to spontaneous questions appropriately.
Assessment	10. Assessing	10 Teachers assess if learning objectives are met during the class.

Description of 4 Main Categories of the KTOP

Philosophy

In the KTOP, constructivism was adopted as a fundamental educational philosophy in science teaching and learning. Therefore, students' active learning, students' metacognitive awareness to their own learning, and the teacher's role as a supporter for students' learning were emphasized.

Basic Goals

Science teaching should help students to achieve the basic goals pursued in a science class. According to the Korean national science curric13ulum, the following five aspects have been emphasized in teaching and learning science in schools: (1) concept, (2) scientific inquiry, (3) NOS, (4) scientific thinking development, and (5) motivation and interest. Understanding scientific concepts and improving scientific inquiry skills are the fundamental and common goals in all science curricula. The "Physics I" curriculum includes such goals as "… to improve inquiry ability based on the nature of science…" (Ministry of Education, Science and Technology [MEST], 2011, p. 85), and goals such as "… to improve creative and integrative thinking ability…" (MEST, 2011, p. 2) are included in the science curriculum for middle school students. The Korean science curriculum also stresses motivation and interest for students of all grade levels.

Activities

Science teaching needs to be planned and organized to encourage students to participate in various active activities. Therefore, it was emphasized that students can connect what they learned in science class with other subjects or everyday life through active cooperation and communication using various learning strategies and materials. Regarding "7. Connection" in Table 3, many science curriculum has stressed the understanding of the relationship among science, technology and society; problem solving ability in everyday contexts; and recently, interdisciplinary integration such as "STEM." The "Teaching and learning methods" standard, which is included in the Korean national science curriculum, encourages creating a prepared teaching plan; using various and effective materials such as technological materials, science books, models, audio-visual materials, software, internet materials; and using various and effective teaching strategies such as mutual cooperation, discussion and debates, open questions, demonstrations, and so on.

Assessment

Assessment allows teachers to check whether or not teaching and learning goals has been achieved. In addition, the Korean national science curriculum emphasizes assessment, including what to and how to assess science teaching and learning. The KTOP includes only formative assessments conducted at the end of a lesson because such a structure focuses on one-hour teaching and learning in the classroom or laboratory.

Validity and reliability of the KTOP

Validity

For high validity of the KTOP

As mentioned earlier, to determine each item of the KTOP, the following four main sources were referred: actual observation of science classes and discussions by five researchers about which aspects needed to be improved, the Korean national science curriculum to consider the basic direction and goals of science teaching and learning in Korea, literature review regarding more authentic and good science teaching, and existing instruments to measure science class, including RTOP and OTOP.

Through the direct observation of actual science teaching, 12 items were extracted as basic elements of the initial version of the KTOP. And after the review process, the initial version of KTOP was revised into 26 items. Finally, this revised version was applied in actual science teaching again, and then finalized to 30 items of 4 main and 10 sub-categories.

Content validity

For obtaining the content validity of the tool, Lawshe's (1975) method with a few revisions was used. We asked 48 science teachers to determine whether each item of the KTOP is important for his/her good science teaching or not. In the survey question, a description about the meaning of each item of the KTOP was provided to help teachers determine the importance of each item. The teachers gave us responses based on the Likert-scale; that is, they evaluated an item's importance on a five-point scale of 5, 4, 3, 2, and 1. The value of "5" corresponded to "strong agreement," "3" a neutral answer, and "1" to "strong disagreement." The result (Table 5) showed the high validity of the KTOP because the average of the responses was 4.4 for all items, 4.2~4.6 for each category, and 4.0~4.6 for each item of the KTOP.

Table 5. Teachers' responses about the importance of each item of the KTOP.

Item category	1			2	3						4						
Item	1-1	1-2	1-3	2	3-1	3-2	3-2	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6	4-7
Response	4.4	4.5	4.5	4.4	4.6	4.6	4.6	4.3	4.2	4.3	4.3	4.6	4.4	4.6	4.5	4.5	4.3
Average	4.4			4.4	4.4						4.4						

Item category	5			6	7		8			9			10
Item	5-1	5-2	5-3	6	7-1	7-2	8-1	8-2	8-3	9-1	9-2	9-3	10
Response	4.5	4.5	4.5	4.6	4.4	4.4	4.2	4.3	4.0	4.2	4.4	4.6	4.5
Average	4.5			4.6	4.4		4.2			4.4			4.5

ISSN 1648–3898

Construct validity

For construct validity, the operational definition of each item in the KTOP was developed to increase the degree to which the KTOP measures what it claims or purports. For convergent validity, concrete examples supporting the operational definition of each item were developed. Lastly, for discriminant validity, counter-examples refuting it were also developed (as shown in Table 1). In this study, though statistical data, such as factor analysis data, were not obtained, it was expected that the operational definition, examples, and non-examples for each item of the KTOP can increase the construct validity.

Reliability

Agreement between raters

Reliability can be obtained by agreement among two or more raters. To do this, Cohen's kappa is usually used for two raters, and Light's kappa or Fleiss's kappa is used for more than three raters (Hallgren, 2012). However, if the rates are inclined toward a one side score, such as a positive or negative score, a kappa value cannot be used because of the so-called "kappa paradox" (Kundel & Polansky, 2003; Viera & Garett, 2005). In our case, if science teaching is well-implemented, then almost all scores of the KTOP would be positive, or the opposite could be true. In this case, the rate of agreement using the formula below is more appropriate than the kappa value (Cicchetti & Feinstein, 1990). For more than three raters, we can use the average of the agreements obtained from all possible pairs of raters.

$$\text{Rate of Agreement} = \frac{Number\ of\ items\ being\ rated\ samely\ by\ two\ raters}{Total\ number\ of\ items\ to\ be\ rated}$$

To obtain the agreement between raters, an in-service program was developed and implemented. In this program, seven physics teachers rated two physics classes and ten earth science teachers rated two earth science classes. In the early stage of an in-service program, that is, before acquiring sufficient expert skills to use the KTOP, the averages of agreements between teachers for two science classes was 0.67. However, in the later stage, the averages of agreement for the other two science classes increased to 0.72~0.90. The averages of agreements between a researcher and teachers were 0.54~0.57 in the early stage, but 0.72~0.88 in the later stage of the in-service course. From these results, it was observed that, after teachers drilled the criteria for using the KTOP, the agreements between raters were high, ranging from 72 to 90%. The detailed information about this in-service program can be found in another paper (Jeong, Park, Park, Kim, & Park, 2014).

Correlation between four observation data

Swada et al. (2002) used the correlation between observers' ratings to estimate inter-rater reliability. The same method was used in this study. In the in-service program mentioned above, seven physics teachers and one of our research teams observed and analyzed two middle school physics classes, and ten earth science teachers and another of our team observed and analyzed two middle school earth science classes. From this, four sets of data were obtained: average score of seven physics teachers and the score of the researcher for each physics class; average score of ten earth science teachers and the score of the researcher for each earth science class (Figure 2). From these data, the correlation coefficient was found to be 0.90 (p=0.096), and the variance shared between the researcher and teachers was 82%. This high correlation means high inter-rater reliability, even though the number of data is too small for a robust analysis at this point.

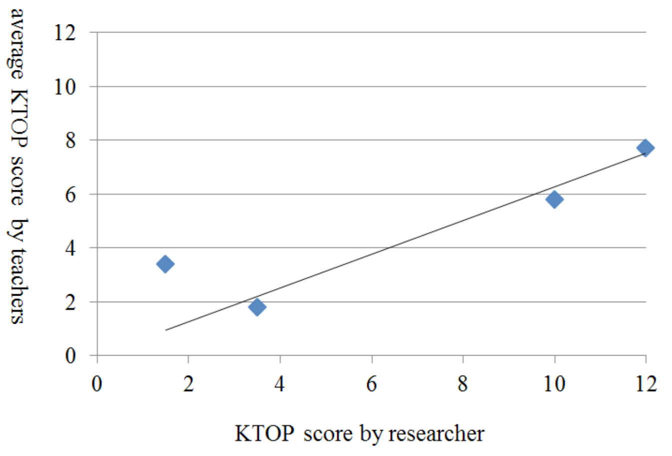

Figure 2: Correlation between researcher and teachers (r = 0.96, p = 0.096, r-squared = 0.82).

Application of the KTOP

Applying to POCOM (Practical On-site Cooperation Model)

The literature notes a gap between educational theory and teaching practice in schools (De Corte, 2000). That is, even though there have been significant advances in educational theories and research, and though teachers are familiar with many of them, actual classroom teaching has not shown a large improvement. In fact, Park, Park, Kim, Jeong, & Park (2014a) also found that Korean science teachers, in their actual science teaching in schools, used only 26% of what they know about educational theories and teaching strategies, even though they agree that the educational theories and teaching strategies are important for their actual science teaching.

As mentioned earlier, to become a public science teacher in Korea, students graduating from the college of education must pass a very competitive national recruitment examination. Because teaching is considered as a favored job in Korea, highly qualified high school students go to colleges of education, which are considered demanding. Therefore, it can be assumed that the level of Korean science teachers' existing PCK and teaching skills are high; the reason for the gap between knowledge and practice may be because such knowledge about the PCK and teaching skills are not activated in actual teaching in schools. Therefore, to activate teachers' existing but hidden professional knowledge, the POCoM (Practical On-Site Cooperation Model) was developed.

In POCoM, researchers observe science teaching directly and use the KTOP to analyze which aspects need to be improved. Then, teacher and researcher cooperate to discuss ideas and methods to improve the KTOP items that need improvement. The improvement ideas and methods are then directly applied to the next teaching. The cyclical process of "observation-analysis-cooperation-application" is continued four times.

As a result, an improvement rate of about 85% on average could be obtained from three teachers (three classroom teaching). When the POCoM was re-applied to the same teachers 1~2 months later, the number of KTOP items needing improvement decreased with statistical significance. Therefore, the effectiveness of the POCoM in improving actual science teaching was maintained after the first cyclic application of the POCoM. More detailed information about the POCoM application using the KTOP can be obtained in another paper (Park, Park, Kim, Jeong, & Park, 2014b).

Applying to an In-service Program

In the original POCoM, the observed teaching using the KTOP was analyzed by researchers. However, teachers can also analyze his/her own teaching or other teacher's teaching, if the teacher can use the KTOP professionally.

To foster this ability, a ten-hour in-service program was developed and implemented for 17 science teachers. In this program, the basic features of the KTOP were introduced first, and then the participants analyzed the first

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video-recorded classroom teaching conducted by another teacher. After the analysis, the participants presented, compared and discussed their analysis results. And they cooperated with each other to produce ideas to improve the KTOP action items in the first video. Participants observed and analyzed a second video and compared their analysis results of the first and the second video..

As noted in reliability section, agreements between teachers were 0.67~0.67 for the first video and 0.72~0.90 for the second video. Agreements between a researcher and a teacher were 0.54~0.57 for the first video and 0.72~0.88 for the second video. From this data, we concluded that the teachers' analysis expertise was increased through the in-service program. More detailed information about this study will be published in the near future (Jeong et al., 2014).

Transforming the KTOP to Different Versions

The original version of the KTOP consisted of 4 main and 10 sub-categories with 30 items. However, this number of items was too large to be checked during science teaching in real time. In fact, according to our study of applying the KTOP to POCoM (Park et al., 2014b), the average number of KTOP items that needed improvement was 11 on average in three teaching classes.

Therefore, to increase the convenience in using the KTOP in real time during a class observation, the number of items of the KTOP should be decreased. However, because all items included in the original version of the KTOP are important for science class evaluation, we cannot exclude any item arbitrarily. In this case, more POCoM studies are necessary to obtain data indicating which items are most checked or least checked. For example, in the study of Park et al. (2014b), the most checked items as needing to be improved in three science classes were 9-3; then 2, 1-1, 6, 9-1, and 9-2; then 1-3 and 3-3; then 3-4; then 8.3, and so on. A smaller version of the KTOP can be suggested with these ten items (9.3, 2, 1-1...). Of course, to develop this more compact instrument, more data should be obtained from more applications of the KTOP to the POCoM.

In addition, using many observed results of one science teacher will help identify the most checked items for that particular teacher. Then, another compact version of the KTOP can be suggested, that is, a "Personal KTOP version." However, these transformed versions of the KTOP have yet to be applied. Therefore, we expect to conduct further studies regarding this point.

Conclusions

In this study, the KTOP for identifying which aspects need to be improved in science teaching was developed with the following four features: (1) The developmental process of the KTOP was designed to diminish the gap between theory and practice using the bottom-up (direct observation of teaching at school) and top-down approaches (literature review, consideration of Korean national science curriculum, and comparing it with RTOP and OTOP). (2) It is specialized for science teaching; therefore, it can be used for improving science laboratory teaching as well as classroom teaching. (3) It is developed for improving science teaching in a more practical way as well as for evaluating it. (4) To do this, it includes concrete examples (which indicate aspects to be encouraged) and counter-examples (which indicate aspects to be improved) developed based on actual observations of science teaching.

As mentioned above, when developing the KTOP, the Korean national science curriculum was considered because it defines basic goals of science education, science contents to be learned in each grade, teaching plans, guides for assessment, and so on. In fact, the Korean national science curriculum has been constructed and reformed considering the curricula of other countries, including 'science for all Americans (American Association for the Advancement of Science, 1993; 1994), 'science education standard' (National Research Council [NRC], 1996; 2000), and 'a framework for k-12 science education' (NRC, 2012) in the US, and 'four key stages' of the national curriculum in the UK (Department of Education, 2013). Therefore, even though the KTOP was developed based on the Korean curriculum, the KTOP can also be utilized in other countries without any changes in each item of the KTOP.

Of course, any single educational theory or tool cannot be applied to all teaching contexts (Loughran et al., 2006; Trianou, 2007) because teaching is context-based. This means that we cannot confirm that the KTOP can be used in other educational contexts in other countries in its original form. Therefore, some items of the KTOP can be revised according to the specific educational situation; then, the KTOP may be renamed to "Revised-ATOP" (here, 'A' denotes the initial of the name of the country).

The KTOP was developed for improving science teaching through observing and analyzing the science class, however, it can be used for other purposes. For instance, it can be applied to develop teachers' expertise in science teaching through pre and in-service teacher program, to examine and to elicit the characteristics of science instruction in different teaching situations, and also can be utilized as an evaluation tool for selecting the capable teachers in the process of teacher recruitment examination, and so on. Thus, we trust that the KTOP can be actively employed in further works.

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