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Elementary Teachers' Conceptions of Science Inquiry Teaching: Cases of South Korea, Singapore and the United States

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과학 탐구 지도에 대한 초등교사의 인식: 한국, 싱가포르, 미국의 초등교사를 대상으로

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국문초록

교사의 과학 탐구 지도에 대한 인식은 실제 수업에서 탐구 지도를 수행하는데 중요한 역할을 할 수 있다. 따라서 교사들이 과학 탐구를 어떻게 인식하는지 이해할 필요가 있다. 이 연구에서는 한국, 싱가포르, 미국 세 국가의 초등 교사를 대상으로 과학 탐구 지도에 대한 인식을 조사하였다. 세 국가는 과학 교육과정에서 탐구를 강조해 온 역사와 설명 방식이 다르며 전반적인 교육적 상황 또한 상이하다. 총 100명의 초등교사(한국 34, 싱가포르 35, 미국31)를 대상으로 설문을 실시하였으며 설문은 구체적인 교수 상황을 서술하는 교수 시나리오, 이상적인 탐구 수업에 대한 내러티브 쓰기로 구성되었다. 데이터는 외적 기준과 내적 관점 모두에서 분석되었다. 연구 결과 교사들의 과학 탐구 지도에 대한 인식은 전반적으로 전통적 견해에 머무르고 있는 특징을 보였다. 그러나 각 국가의 교육과정에서 탐구가 서술되고 강조된 방식에 따라 차이가 나타나기도 하였다. 이러한 결과가 교사교육에 주는 시사점을 논의하였다.

주요어 : curriculum, educational contexts, elementary teachers, science inquiry teaching, teachers’ conceptions

I. INTRODUCTION

Science inquiry has a long history in the discourse on science education (DeBoer, 1991; Schwab, 1962) and is currently promoted as a primary goal of science education and as a tool for science instruction in international communities of science education (Abd-El-Khalick *et al.,* 2004). Despite the significant status of science inquiry in science education, the notion of inquiry teaching has not been directly addressed in reform documents; rather, only general characteristics or some images of inquiry teaching practices are provided (BSCS, 2006; Northern Territory Government Australia, 2009; Millar & Osborn, 1998; NRC, 2000) to have teachers form their own meanings of inquiry teaching (Keys & Bryan, 2001). Given the situation, it is no surprise to find repeatedly that science inquiry in the classroom is mostly incongruent with visions of inquiry in reform documents in the US (Anderson, 2002; Wallace & Kang, 2005) as well as in other countries (Abd-El-Khalick *et al.,* 2004).

The notion of science inquiry as practices of scientists has been discussed in the literature on the nature of science among science educators (Lederman, 2007), and there seem to be some features of scientific inquiry that relevant research communities commonly suggest to be addressed in science classrooms (AAAS, 1990; Osborne *et al.*, 2003; McComas & Olson, 1998). However,

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science inquiry as a teaching approach is expected to vary across different educational settings because different educational conditions are conducive to different forms of teaching practices. As teachers play a significant role in shaping students' learning experience, an understanding of teachers' perspectives on inquiry teaching is an essential first step for understanding science inquiry in the classroom.

From a view that human minds are mediated by historical, cultural, and institutional contexts (Bakhtin, 1981; Wertsch, 1991), teachers' perspectives on inquiry teaching are expected to reflect educational contexts. The ways in which educational contexts mediate beliefs and practices can be effectively examined through cross-national/cultural comparative studies in which differences in beliefs and practices can be connected to differences in educational contexts (Alexander, 2000; Osborn, 1999; Spindler & Spindler, 1987; Stigler & Hiebert, 1998). Furthermore, comparisons of educational beliefs and practices in different educational contexts can also shed light on possibilities beyond what is taken for granted in a given context. Thus, examining teachers' perspectives on inquiry teaching in relation to various educational contexts can suggest what different contexts offer to each other about improving educational conditions for inquiry teaching.

This study concerns three nations including Singapore, South Korea, and the US that have different educational systems (Martin *et al.*, 2008; Mullis *et al.*, 2008; OECD, 2007; Stigler & Hiebert, 1999). By identifying similarities and differences of teachers' perspectives on inquiry teaching from the three different educational contexts, this study aimed to understand how educational contexts factor into teachers' perspectives. The purpose of this study was to explore elementary teachers' ideas about science inquiry teaching with small samples from the three nations and to delineate similarities and differences in teacher perspectives. Three research questions guided this study: (1) To what degree are the elementary teachers' conceptions of inquiry teaching consistent with those promoted in the current science education reform? (2) How do teachers characterize classroom inquiry from their perspectives? (3) How do teachers' conceptions reflect their teaching contexts? The findings would provide implications for elementary science teacher professional development programs about inquiry teaching as well as improvement of educational contexts.

In this study, educational context is discussed mainly based on the structure of current curriculum and the discourse of inquiry approach introduced in the curriculum of each country. Due to the methodological choices in this study, it seems more appropriate that we limit the scheme of educational context to the structural framework of inquiry-based science curriculum rather than to expand it to educational systems or educational culture. Thus, based on the specific scheme, we looked into how teachers perceive and understand science inquiry teaching in three countries.

1. Relevant Educational Context of Each Country

The three nations are different in the way inquiry teaching is introduced and promoted in formal science education. Singapore has about 5 million people and is a multicultural nation with a majority of Chinese immigrants and substantial Malay and Indian minorities (Department of Statistics Singapore, 2011). The country has four official languages, while English is used in schools. At the end of the final year of elementary school, all students take Primary School Leaving Examination (PSLE) to get a graduation diploma and to enter middle school (Gov Monitor, 2010). Singapore has a centralized education system in which a national science syllabus guides school science. Inquiry teaching has recently been emphasized in the syllabus when the new primary science syllabus was introduced to public schools in 2008. In the syllabus, inquiry became an overarching frame of science education: "Central to the curriculum framework is the inculcation of the spirit of scientific inquiry" (Ministry of Education Singapore, 2007). The inquiry-based curriculum describes students "as the inquirer" and teacher "as the leader of inquiry" (Ministry of Education Singapore, 2007). To achieve the goal of inquiry-based science curriculum, there have been efforts such as reforming science textbooks to be theme-based and developing inquiry teaching materials and resources for teachers to practice inquiry-based curriculum in their classrooms. Moreover, hundreds of teachers participate every year in inquiry workshops and in-service courses organized by the National Institute of Education and Ministry of Education. In those workshops and courses, various models of inquiry teaching are introduced including BSCS 5E model (Bybee *et al*., 2006), Problem-based learning, informational technology integration model, and others (e.g., Poon *et al*., in press).

South Korea has 49 million people (The World Bank, 2011) and is ethnically and linguistically homogeneous. The education system is centralized in that a national curriculum is produced by a government agency, and all elementary schools use the same textbooks. Unlike Singapore, no high stakes test is administered at the elementary level. The national science curriculum has been influenced by the US science reform ideas since 70s' (Ministry of Education Korea, 1997). The term inquiry first appeared as a goal of science education in the 1973 National Science Curriculum in which student inquiry capacity was conceptualized as a key academic aptitude. In early 90s', the academic focus shifted to general education in which elementary science was defined, "science is a subject to develop basic scientific literacy in which basic ability to inquire natural objects and phenomena is developed, basic concepts are understood through scientific inquiry process, and proper scientific attitudes are developed" (Ministry of Education Korea, 1997). In the curriculum, inquiry was stated as a way to learn scientific knowledge as well as goal of science education in itself.

The US has about 307 million people (The World Bank, 2011) and is ethnically and linguistically diverse. The educational system in the US is locally governed in that curricula, assessment, funding and relevant policies are under the jurisdiction of school districts with directives from state legislatures. At the same time, federally funded educational reform efforts have guided national trends in science education. Science inquiry has long been in such reform efforts (DeBoer, 1991; NRC, 1996, 2000; Schwab, 1962). In the 60s' many science curricula were produced through federally funded projects in which inquiry for future scientists was emphasized. These efforts were found to be unsuccessful due to its lack of attention to teachers' role in translating the curricula into classroom teaching practices. Inquiry turned into mindless activities or cookbook labs (e.g., Roth *et al*., 2006; Tobin, 1986). From the realization of the importance of teacher role, the recent science education reform in the US emphasizes teaching aspect of inquiry and professional development of teachers (NRC, 1996). Because of the localized educational system, however, the national emphasis on inquiry might not be directly shown or implemented in states and local school districts (Kirst, 1994). Depending on the degree to which state standards and local curricula are aligned with those of national reform agenda, therefore, the emphasis on inquiry teaching varies (e.g., Abd-El-Khalick *et al*., 2004). Furthermore, the variation can be extended when teachers develop their own inquiry lessons (Wallace & Kang, 2004).

The background and emphasis on inquiry in the curriculum and classroom practice has been different among three countries. In the US, inquiry has been emphasized since 1960s while it is in some degree a recent phenomenon in Korea and Singapore. In Korea, even if science inquiry has been recognized in the curriculum since the 70s, there has not been sufficient elaboration on the nature and methods of inquiry teaching. In Singapore, science inquiry is not new, but its emphasis is much more distinctive in the recent curriculum and classroom practice.

2. The Nature of Inquiry in Curricular Documents or Standards

Discussions on inquiry in science education have distinguished inquiry as what scientists do from inquiry activities involved in teaching and learning science (Colburn, 2000). The distinction of the two suggests differences between inquiry done by scientists and inquiry done by students indicating that inquiry teaching does not require students to behave exactly like scientists. In this study, we focus on inquiry as a pedagogical approach, i.e., classroom inquiry. In this section, the nature of classroom inquiry in the curriculum or standards is examined.

1) US: Inquiry as Multi-faceted Activities

Inquiry as a pedagogical approach has a long history in the US, dating back to 19th century (Bybee, 2000). The nature of science inquiry in the 21st century science education in the US is elaborated in the addendum to the National Science Education Standard (NRC, 2000). The content standards for science inquiry include both ability to do inquiry and understanding about scientific inquiry. For example, a statement, "plan and conduct simple investigation" is presented as one of "fundamental abilities necessary *to do* scientific inquiry (italics added)" for grades K-4. At the same time, a statement, "scientists use different kinds of investigations depending on the questions they are trying to answer" is presented as one of "fundamental *understandings about* scientific inquiry (italics added)" for grades K-4. Scientific inquiry is clearly distinguished from classroom inquiry in the US standards document, and ability to do inquiry and understanding about scientific inquiry are both aimed as science learning outcomes.

Classroom inquiry in the recent reform document is described as complex and multifaceted activities that have various approaches:

> making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (pp. 13-14).

Sorting out these complex activities the document emphasizes scientific questions, evidence, and explanations and presents five "essential features of inquiry" to guide inquiry teaching:

> Learners are engaged by scientifically oriented questions [EQ]; Learners give priority to evidence [EV]; Learners formulate explanations from evidence to address scientifically oriented questions [EX]; Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding [EK]; Learners communicate and justify their proposed explanations [EC] (p. 25).

Instead of terms such as experiments and data that were prevalent in the traditional notion of scientific method, the five essential features highlight terms such as evidence, explanation, evaluation and justification to indicate an image of classroom inquiry as a process of constructing evidence-based explanations for answering scientific questions. Furthermore, reflecting on the recent changes in view of scientific inquiry (e.g., Giere, 2006) social aspects of scientific inquiry such as evaluation of various explanations (EK) and justification (EC) emerged as critical for students to practice in the classroom.

To these features the document adds variations by the degree to which students direct their inquiry activities as opposed to teachers or lesson materials do so. For example, a variation of engaging in scientifically oriented questions includes a learner poses a question, selects a question, sharpens a question, or answers the question posed by the teacher, materials or other sources. Therefore, inquiry is described in two dimensions-features of inquiry activities and the level of student self-direction.

2) South Korea: Inquiry as Process Skills and Activities

Differently from the US standards, there is no explicit description of inquiry in the national curriculum and no distinction made between scientific inquiry and classroom inquiry. In the curricular content overview of the national science curriculum at the time of the study, inquiry was divided into inquiry process skills and inquiry activity. Inquiry process skills was further divided into (a) simple process skills such as observation, inference and measurement, and (b) complex process skills such as identifying inquiry questions, constructing hypothesis, controlling variables, constructing conclusions and generalization. The inquiry activity category included experimentation, investigation, field trips, research projects, and so on. This list of inquiry process skills and activities has been in the national science curriculum for decades as curriculum contents. In the description of science curricular content, inquiry process skills are integrated with science contents. For example, a fifth grade topic on "Functions of plant leaves" has a content description stated, "*Through an experiment of extracting starch from a leaf that has and has no exposure to sunlight*, students understand that plants use light in photosynthesis and produce starch (italics added)". Practice of science inquiry process skill (controlling variables) and activity (experimentation) is integrated with science concept (photosynthesis) learning. The curricular content description indicates that inquiry process skills and activities are to learn science content. There were also several content statements that are primarily for inquiry process skills development. For example, contents for fourth grade included, "Measure the growth of green beans while controlling variables such as water and light." and "Make a spring balance and weigh various objectives". Without clear definition, inquiry process skills were presented as a way to learn science content and learning goals in themselves.

3) Singapore: Inquiry as Orientation for Knowledge, Skills and Processes, and Attitudes

The national syllabus defines inquiry "as the activities and processes which scientists and students engage in to study the natural and physical world around us" (Ministry of Education Singapore, 2007) and presents the five essential features of inquiry promoted in the US standards in its guide for teaching and learning approaches. The Syllabus presents three domains of the curriculum content: (a) Knowledge, Understanding and Application, (b) Skills and Processes and (c) Ethics and Attitudes. 'Skills' and 'processes' are distinguished in the Syllabus, that is, 'skills' includes individual inquiry skills such as observing, comparing, classifying, analyzing, formulating hypothesis and 'processes' includes integrated inquiry skills such as creative problem solving, decision-aking, and investigation. The three domains are related in the curricular content descriptions. For example, regarding the concept of force, the knowledge domain includes, "Recognize that a magnet can exert a push or a pull," the skills and processes domain includes, "Compare magnets and non-magnets", and the ethics and attitudes includes "Show curiosity in exploring magnets and question what they find". These three statements are presented hand in hand indicating its connected nature while their distinct identity is kept. Unlike Korean curriculum content statements, there is no content statement exclusively for developing inquiry skills in themselves because all inquiry skills and processes are matched with knowledge and attitudes.

Inquiry in the curricular or standards documents of the three countries demonstrates some differences. The classroom inquiry in the US standards is described more holistically with distinct components, but connections to content are not explicitly made. In the Korean curricular document, inquiry is not explicitly defined, but classroom inquiry is described in terms of process skills and activities that are either stand-alone learning contents or ways to learn science concepts. In defining the nature of classroom inquiry, the Singaporean curricular document is influenced by the US standards, but inquiry as curricular contents is closely related to science knowledge, skills and processes, and attitudes while the three remain as distinct curricular content domains.

3. Teachers' Beliefs about Inquiry Teaching

What teachers know and believe impact their decisions in planning and carrying out their plans. Some studies provide evidence that teaching practices are informed by teachers' beliefs about inquiry, students, educational goals, and other related parts of classroom teaching (Crawford, 2000; Wallace & Kang, 2004). Recently, Kang *et al*. (2008a) examined secondary science teachers' conceptions about inquiry teaching using the five essential features of inquiry described in the US reform document to understand how closely teachers' conceptions were aligned with the reform visions. The findings showed that teachers' conceptions rarely included two features of inquiry: 'Learners evaluate their explanations in light of alternative particularly scientific explanations' and 'Learners communicate and justify their proposed explanations.' The findings suggest that the teachers' views about inquiry are limited to the traditionally promoted activities while the new aspects of inquiry that encompass inquiry activities of theory or model development and argumentation are largely missing.

Research has shown that teachers develop their own ideas about what inquiry teaching is (Keys & Bryan, 2001; Wallace & Kang, 2004). Such seemingly individual ideas, however, reflect commonly shared educational contexts because it provides tools with which meanings are constructed (Bruner, 1996). For example, in a comparative study, Swain *et al*. (1999) found that secondary school science teachers had different goals for practical work and their goals reflected their national teaching contexts. In the study, teachers in the UK were concerned about developing students' problem solving and reasoning skills through practical work. This was consistent with the national curriculum emphasis. On the other hand, the Korean teachers focused on content understanding through practical work, which was consistent with the national emphasis on competitive content exams. In contrast to the two countries, teachers in Egypt had few purposes of practical work as they rarely used practical work due to lack of facilities and large class sizes. This study suggests that there are national patterns that are consistent with the nation's educational context.

Based on the theoretical and empirical discussions, this study anticipates that teachers in different nations could develop different ideas on how to teach science inquiry where there are different ways to introduce and highlight inquiry in the curriculum and also other relevant educational contexts such as national assessment and textbooks.

II. METHOD

1. Participants

In all three nations, elementary teachers in general teach all subject matters in a self-contained classroom. In order to obtain rich data, therefore, we recruited teacher participants from professional development workshops on science inquiry to ensure involving teachers who were interested in science teaching and science inquiry in particular. However, we collected data at the beginning of the workshop in order to avoid any immediate influence of the workshop on teacher responses. The teachers volunteered for the workshop while none of the research members were directly involved in the workshop. A total of 100 teachers with various years of teaching experience participated (Table 1).

2. Data Collection

The main data source was a classroom scenario response survey and teachers' narrative writing of an ideal inquiry lesson. Among various methods to probe teachers' belief and knowledge scenario responses have been reported to be particularly useful for assessing teacher practical knowledge and beliefs because they are context sensitive (Bybee, 2000; Kang *et al.*, 2005; Nott and Wellington 1995). In this study we used a teaching scenario survey instrument developed by Kang *et al.* (2008a). The scenario response survey was originally developed for secondary science teachers based on the five features of inquiry elaborated in the US national science education reform documents and validated by comparisons with group discussion.

In the survey, the teachers are asked to indicate if each scenario is an example of classroom inquiry (yes

Table 1. Teacher participant profile

Country	Number of respondents	Gender		Years of teaching experience			
		Male	Female	5 years or less	5～10 years	10～20 years	20 or more years
Korea	34	19	15	9	17	8	0
Singapore	35	7	28	11	9	8	7
U.S.	31	4	27	4	12	11	4
Total	100	30	70	24	38	27	11

or no) and then asked to explain the reasoning behind their decision and to describe how each scenario could be modified to be more inquiry oriented. By using a pre-established framework, we intended to compare teacher beliefs in a coherent way. Two of ten scenarios used in the original scenario survey were modified in order to make the scenarios appropriate for elementary classroom settings that were likely to occur in the three countries (Appendix). To survey Korean teachers, a Korean version of the survey was constructed through an iterative process of translation into Korean and then reverse-translation into English.

In order to complement and triangulate the data on teacher perspectives, we also used the second data collection method, i.e., narrative writing in which the teachers were asked to write a narrative describing a successful inquiry lesson in their classrooms. The narrative writing was to examine the nature of inquiry lessons as a whole. Not all teachers completed narrative writing. A total of 73 teachers (32 Korean, 20 Singaporean, and 21 US teachers) completed narratives.

3. Data Analysis

Data analysis involved two phases using a content analysis method (Miles & Huberman, 1994; Patton, 1990). We first analyzed scenario responses and teacher narratives using the five essential features of inquiry described in the US Standards document as a content analysis framework. We used the five features of inquiry because we were interested in comparing to the previous research (Kang *et al*., 2008a) and also examining the degree to which teachers' conceptions reflected the recent view of scientific inquiry included in the five features.

The second phase was to examine features of inquiry from the teacher perspective by utilizing teachers' language. We analyzed teacher explanations for their scenario responses and narratives through open-coding process (Strauss & Corbin, 1990) in which we compiled a comprehensive list of teachers' language that described what constituted inquiry in the classroom.

The data was also analyzed statistically by analysis of variance (ANOVA) among three countries.

4. Reliability

The three researchers of this project are appropriate for the study in that they are science teacher educators in each country and have been involved in providing professional development for in-service elementary teachers. Also, one of them has been engaged in international comparative studies for the past decade (e.g., Kang *et al*., 2008b).

Each researcher coded all the data independently and then discussed each one's coding over several meetings to come to a consensus. In the initial open coding, 79% of data coding was consistent. We discussed differences in coding and coded the inconsistent data independently again. By repeating this process, we resolved any inconsistency. In the process, we carefully followed coding rules presented in the previous study (Kang *et al*., 2008a). Multiple data source triangulation (Patton, 1990) was used by comparing the scenario responses with narrative writing data. Because the scenarios were written based on pre-established notion of inquiry, we suspected that teacher responses would be confined. Therefore, the open-ended nature of narrative writing was expected to provide what was not tapped into through scenarios. Therefore, the triangulation was not only for identifying convergences but also for divergences (Mathison, 1988).

III. RESULTS

1. Five Essential Features of Inquiry in Teachers' Conceptions of Classroom Inquiry

1) Salient Features of Inquiry

Using typical inquiry teaching scenarios, we identified the degree to which the five essential features of inquiry were highlighted in the teachers' conceptions of classroom inquiry. Because each scenario focused on one feature of inquiry, teachers were expected to mention several missing aspects to make a scenario to be more inquiry-oriented. As such, the analysis of teacher responses focused on identifying which aspects of inquiry from the five essential features were frequently mentioned. It was assumed that the more the teachers mentioned a certain inquiry feature, the more the feature was salient in their conceptions. By calculating the percentage of each feature mentioned based on total frequency of inquiry features stated, the scenario responses therefore revealed the relative emphasis of certain features of inquiry while equal emphasis (20% each) was desired because all five features were deemed to be essential to inquiry. The analysis was completed for the responses of the teachers from each nation (Fig. 1).

The result demonstrated similarities and differences in teachers' conceptions of inquiry. The feature of gathering evidence (EV) was frequently mentioned by the teachers in all three nations. In contrast, the teachers in all three countries rarely mentioned the social aspects of inquiry, i.e., the feature of evaluating and con necting inquiry results to scientific knowledge (EK) and

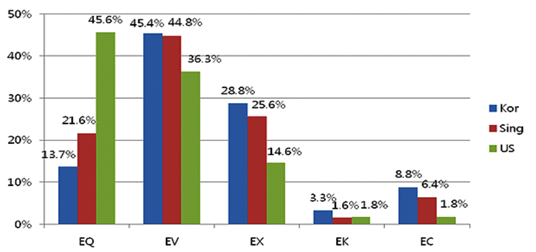

Fig. 1. Emphasized features of inquiry

communicating and justifying inquiry results (EC). This lack of attention to EK and EC was consistent with the previous research on a group of secondary teachers in the US (Kang *et al*., 2008a).

Differences in responses from the teachers in the three different nations were found (Table 2). The US teachers mentioned inquiry questions much more frequently (p<0.01) than the others while the Korean and Singaporean teachers mentioned the feature of gathering evidence (EV) and constructing explanations (EX) more frequently than the US teachers (p<0.05). Overall, the US teachers emphasized questions and evidence gathering processes the most (EQ & EV), the Korean teachers and the Singaporean teachers emphasized evidence gathering and construction of explanations the most (EV & EX). Less emphasis on scientific questions in Korea and Singapore seems to be related to their dependency on textbooks in classroom teaching. In particular, in Korea, the same science textbook is used throughout the nation. The textbooks provide inquiry tasks or questions for students and thus there is little room for formulating scientific questions on their own.

2) Inquiry Lesson Elements

While the teachers' scenario responses revealed the

Table 2. Differences in emphasis on the essential features of inquiry (ANOVA)

		Sum of squares	*df*	Mean square	*F*	Sig.	Post hoc tests
EQ	Between groups	18,836.0	2	9,418.0	23.4	0.00	US > Singapore > Korea
	Within groups	36,610.8	91	402.3			
	Total	55,446.8	93				
EV	Between groups	2,661.1	2	1,330.6	3.3	0.04	Korea, Singapore > US
	Within groups	37,166.7	91	408.4			
	Total	39,827.9	93				
EX	Between groups	2,295.1	2	1,147.5	3.8	0.03	Korea > Singapore > US
	Within groups	27,578.0	91	303.1			
	Total	29,873.1	93				
EK	Between groups	84.9	2	42.5	1.8	0.18	
	Within groups	2,201.2	91	24.2			
	Total	2,286.1	93				
EC	Between groups	1,223.9	2	612.0	7.7	0.00	Korea > Singapore, US
	Within groups	7,267.0	91	79.9			
	Total	8,491.0	93				

features of inquiry emphasized as defining features, narratives illustrated which features of inquiry were included in inquiry lessons as regular or typical aspects of inquiry. We therefore examined combinations of inquiry features present in the teachers' narratives of inquiry lessons. Not surprisingly, no lesson narrative had all five features. Just as scenario responses revealed, the teachers described lessons that had the features of traditional inquiry (EQ, EV, EX) the most. Although scenario responses showed the Korean teachers' less emphasis on scientific questions (EQ) and the US teachers' less emphasis on evidence and explanations (EV, EX), their narratives were very similar. We identified 53% of lessons described by the Korean and US tea chers that had the three features (EQ, EV, EX). Interestingly, the narratives of the Singaporean teachers did not show five essential features distinctively. Less than one third of the narratives were coded by five features. Instead, the teachers emphasized cooperative group work as important features of inquiry (42%) and most of the lessons they described had student activities and the teachers' explanations of how the activities were relevant to scientific concepts (53%). A few narratives explained that implementing models such as the 5E model, a learning cycle or Prediction-Observation-Explanation (POE) as a lesson frame would be inquiry teaching. The dominance of knowledge connection in the narratives of Singaporean teachers seemed to reflect their teaching context in which inquiry processes and skills were closely related to knowledge in the national curriculum and concerns about Primary School Leaving Examination (PSLE).

2. Features of Classroom Inquiry from Teacher Perspectives

Along with content analysis, we used generic qualitative method (Miles & Huberman, 1994) for analy zing the features of inquiry based on the direct utterance of respondents. In analyzing the responses by generic method, we attempted to get comprehensive lists to include every feature we could recognize and then group those into several dimensions based on common properties across all data: aspects of inquiry, student-centered and the nature of task (Table 3).

Table 3. Characteristics of inquiry teaching: teacher perspectives

Characteristics of inquiry		Meaning	Example
Aspects of inquiry	Inquiry skills (IS)	Students are involved in data collection processes including observation, classification, measurement, etc.	"Through the process of gathering data, it can be a part of inquiry teaching" "Classification is one of basic inquiry skills"
	Hypothesis testing (HT)	Students generate and test a hypothesis.	"It is an inquiry because it is a process of verifying their hypothesis"
	Sharing (SH)	Students present/discuss their own process and results.	"Communicating results/data collection is part of the inquiry process."
Student-centered	Student self-direction (SD)	Students should initiate or actively engage in the process of inquiry.	"Students need to decide their process of experiment by themselves."
	Student thinking (ST)	Inquiry makes students think.	"Because the discussion needs critical thinking", "think by themselves", "higher order thinking", "creative/ logical/critical thinking"
	Student curiosity (SC)	Inquiry triggers student interests and/or curiosity.	"This sparks off their interest and curiosity about things around them"
Nature of task	Knowledge application (KA)	Applying one's knowledge to new context to explain something.	"They have to apply relevant concepts to work"
	Problem solving (PS)	Finding an answer to a problem.	"Because it is an activity of finding problem and making the things better"
	Open-ended (OE)	The result should not be pre-determined; Diverse methods and answers should be allowed.	"Because it needs diverse perspectives and diverse methods" "Have students come up with their own ways to classify a group of plants and then compare to standard classification system"

The salient and common trends across the three nations, when coded from the teacher perspectives, were that the teachers perceived inquiry mostly as student-centered activity (SD) and/or gathering and processing information (IS) while the social aspect of inquiry gained minimal attention noted by a term "sharing" (SH). These results were similar to the analysis of five essential features in the previous section.

In addition to the commonalities, differences were also found (Table 4). Among the nine characteristics of inquiry teaching in the teachers' terms, IS, HT, SD, and ST were relatively emphasized in varying degree across the three nations.

1) Aspects of Inquiry

The analysis of using teachers' language made differences in teacher conceptions of inquiry clearly visible. The Korean teachers used terms such as "inquiry skill" and "inquiry process" (IS) the most in defining inquiry (37.8%). The American teachers emphasized "hypothesis testing" (HT) more than other two countries ($p<0.05$).

The Korean teachers' emphasis on inquiry process skills was reflective of their national curricula in that the decades of emphasis on inquiry process skills in Korean curriculum might explain the Korean teachers' strongest emphasis on inquiry process skills as defi-

Table 4. Differences in teachers' perceptions of inquiry teaching: emic perspectives (ANOVA)

Characteristics of inquiry		Sum of squares	*df*	Mean Square	*F*	Sig.	Post Hoc Tests
IS	Between groups	2,482.0	2	1,241.0	2.6	0.07	Korea > Singapore, US
	Within groups	44,879.9	95	472.4			
	Total	47,361.9	97				
HT	Between groups	3,108.3	2	1,554.2	5.1	0.01	US > Korea, Singapore
	Within groups	29,121.0	95	306.5			
	Total	32,229.4	97				
SH	Between groups	133.1	2	66.6	0.7	0.52	
	Within groups	9,503.5	95	100.0			
	Total	9,636.6	97				
SD	Between groups	4,944.5	2	2,472.3	5.9	0.00	US, Singapore > Korea
	Within groups	39,761.6	95	418.5			
	Total	44,706.1	97				
ST	Between groups	1,310.7	2	655.3	3.4	0.04	Korea > Singapore, US
	Within groups	18,352.7	95	193.2			
	Total	19,663.4	97				
SC	Between groups	450.2	2	225.1	3.9	0.02	Singapore > Korea, US
	Within groups	5471.4	95	57.6			
	Total	5921.6	97				
KA	Between groups	400.5	2	200.2	2.5	0.09	Singapore > Korea, US
	Within groups	7752.3	95	81.6			
	Total	8152.8	97				
PS	Between groups	102.2	2	51.1	0.5	0.63	
	Within groups	10338.5	95	108.8			
	Total	10440.7	97				
OE	Between groups	43.7	2	21.8	2.2	0.12	
	Within groups	947.9	95	10.0			
	Total	991.5	97				

ning features of inquiry.

As for the US teachers' emphasis on hypothesis testing as a defining feature of inquiry, the analysis of narratives provided some insight. When the nature of hypothesis was examined in the narrative writings of the US teachers, hypotheses were mostly related to scientific questioning. First of all, many of the US teachers used the term "a testable question." Moreover, the nature of hypothesis teachers exemplified in their narratives was all prediction of phenomena (e.g., "Have students predict which objects will sink and float and then have them test objects…"). In other words, inquiry questions were questions about predictions that were equated with hypotheses.

2) Student Involvement

The teachers also used student involvement as a defining characteristic of inquiry (the second cluster in Fig. 2). They refined student involvement into student self-direction (SD) in the process, student thinking (ST) and student curiosity and interest (SC). The Singaporean and the US teachers emphasized student self-direction in the process more than Korean teachers ($p<0.01$) while the Korean teachers emphasized student thinking more than the teachers of the other two countries ($p<0.05$).

As for the Korean teachers' emphasis on student thinking as a defining feature of inquiry, the analysis of narratives provided some insight. In their narratives, the Korean teachers' notion of thinking was very general and did not indicate specific forms of reasoning they expected students to utilize during inquiry. Furthermore, they seemed to put student self-direction and

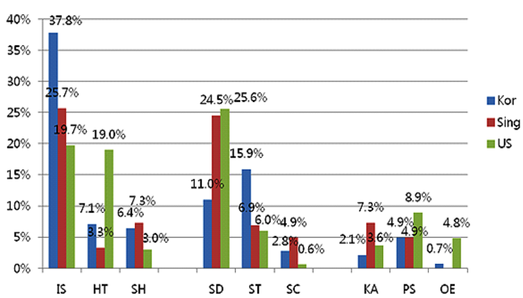

Fig. 2. Features of inquiry from teacher perspectives

thinking side-by-side often. For example, a teacher concluded her lesson narrative with a description of inquiry as the following: "It (inquiry) is not doing just what they are told to do. They need *time to think* on their own feet…. They should be allowed to *conduct their experiments according to their thoughts*… (Italics added)." The Korean teachers seemed to consider inquiry activities as opportunities for cognitive engagement in the general term of "thinking" and considered student self-direction in terms of following their ideas. Therefore, the seemingly lower emphasis on student self-direction in the process was due to their putting student thinking forefront. In response to scenarios, thus it was likely that a teacher might have mentioned student self-direction that might mean student thinking and vice versa.

3) Nature of Inquiry Tasks

Sometimes the teachers characterized inquiry in a holistic manner, in addition to detailed features, by characterizing the nature of inquiry task as a whole. The teachers used terms such as "knowledge application" (KA), "problem solving" (PS) or "open-ended" (OE) (the third cluster in Fig. 2). Such a broad characterization of inquiry was consistent with the teachers' decisions on inquiry scenarios. Among the 10 scenarios, most teachers from all three nations agreed on four scenarios in terms of whether each scenario was inquiry or not. More than 80% of teachers in all three nations decided four activities (items 2, 3, 5 and 9) as inquiry. In these activities, students construct solutions to problems that were open-ended and/or required application of knowledge. Although the responses in this dimension were not found frequently, it was notable that the Singaporean teachers emphasized "knowledge application" more than the teachers of the other countries ($p<0.10$).

Ⅳ. DISCUSSION AND CONCLUSION

This study examined teachers' conceptions of classroom inquiry from both normative and emic perspectives. From the normative perspective, the findings showed that the teachers' conceptions were confined to the traditional view of inquiry that largely missed recent model of scientific inquiry. This finding was consistent with the previous study on a sample of secondary science teachers in the US (Kang *et al.*, 2008a). The teachers' focus on the traditional view of inquiry was also clearly shown in the analysis from the teachers' perspectives. The teachers in all three nations highlighted the traditional notions such as inquiry process skills and hypothesis while paying minimal attention to the social aspect of inquiry such as evaluation of various explanations among students and justifications (EK, EC or SH).

The exclusion of social aspects of inquiry in the teachers' conceptions implied missed learning opportunities for students and suggested what should be focused on during teacher professional development on inquiry. Given the current view of scientific inquiry, the classroom inquiry without social aspects as a significant part would convey a distorted view of scientific inquiry. Also, students miss the opportunities to practice the social aspects of inquiry such as argumentation that is a basic scientific literacy skill (e.g., Millar & Osborne, 1998; NRC, 1996). Furthermore, the lack of social activities deprives valuable mode of learning in which students construct meanings through social interactions (e.g., Tobin, 1993). For student learning, therefore, teachers' inquiry conceptions should be extended to include social aspects of inquiry as key features.

The findings indicate some consistencies between the national curriculum and the teachers' conceptions of inquiry teaching to some degree. The consistencies indicate that the curriculum is also responsible for the dominance of inquiry process skills emphasis in the teacher conceptions. In return, the consistencies suggest what a curriculum can do in guiding teachers. Long-term and consistent promotion of inquiry through curricular content might be a way to affect teachers' conceptions and thus classroom teaching practices (Ball & Cohen, 1996). Therefore, the needed professional development content aforementioned should also be emphasized in the national curriculum as well as professional development.

The unique responses of the Singaporean elementary teachers as to their inquiry conceptions suggest a possible path of teacher professional development. The teachers' mention of cooperative learning and inquiry models as their inquiry lessons might reflect the current efforts to bring forth inquiry emphasis in classroom practice through professional development. Given that teachers vastly participate in various occasions of professional development, it would be meaningful to examine how teachers' perceptions and practices of inquiry would further develop through professional development programs over time. The Korean teachers' relatively high emphasis on the aspect of student thinking as a critical feature of inquiry activities is also noteworthy. While the findings support the ongoing criticism on mindless hands-on activities in the science classrooms (Flick, 1993; Roth *et al*., 2006) and promote challenging teachers' perceptions of inquiry to focus on student thinking, the vague notion of thinking involved in inquiry activities suggest that science educators should discuss and refine what would be the specific forms of thinking that students need to develop during their inquiry process.

Similarly, the less sophisticated notion of hypothesis involved in science inquiry, as clearly demonstrated by the US teachers, suggest that science teacher educators should provide teachers with opportunities to examine the meaning of hypothesis in science inquiry as well as inquiry teaching. Given the prevalent exclusion of EK and EC in teachers' conceptions of inquiry, equating prediction with hypothesis may lead to a misunderstanding of scientific inquiry only for prediction of phenomena. There should be further discussion on the degree of simplification for elementary level inquiry to avoid or minimize these issues.

This study is not for a generalized description of teachers' conceptions of inquiry teaching but for some insight into a way to understand teachers' conceptions of inquiry teaching and a guide for further research. We propose in this paper some content for professional development needed for elementary teachers and what each country can learn from each other. While this exploratory study needs to be augmented by further research, more exploratory studies involving other countries with varying educational contexts will enrich our understanding of elementary teachers' conceptions of science inquiry.

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Appendix: Scenario items

1. Having students gather data for a local non-profit organization.
2. Giving students a white powder and asking them to determine what the powder is.
3. Asking students to develop and answer their own questions about their living environments.
4. Having students follow a procedure to complete a lab.
5. Asking students to use what they know about a local forest to decide whether an old folks home should be built on that land.
6. Having students classify substances based upon their observable properties.
7. Having students use graphics on the Internet to explain about water cycle. *
8. Having students make presentations of data collected during lab.
9. Asking students to improve on a basic design (make an airplane fly further, make a motor spin faster, etc.).
10. A class discussion about the plant classification. *

* Modified from the original version (Kang *et al*., 2008a) with consideration of elementary school science contents.