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

Hye-Gyoung Yoon (Chnucheon National University of Education)

Nam-Hwa Kang (Oregon State University)

Mijung Kim (University of Victoria)

Correspondence to

Hye-Gyoung Yoon
Chuncheon National University of Education
Seoksa-dong 339, Chuncheon-si, Gangwon-do
Republic of Korea 200-703

Tel: + 82 33 260 6468
Fax: +82 33 264 3028
Email: yoonhk@cnue.ac.kr

Abstract

With a long history, science inquiry has been a primary goal of science education in international communities of science education. Given that its vision has been promoted internationally and its implication has been a challenge in local classrooms, this study aims to understand how elementary teachers perceive science inquiry teaching and what could be suggested to develop inquiry teaching in their educational contexts. The study invited elementary teachers in three different countries, Singapore, South Korea, and the US. We attempted to understand what are the similarities and differences in teachers' conceptions of inquiry teaching in relation to curriculum reformation, classroom practice by engaging them in survey questionnaires, inquiry scenario survey, and narrative writing on inquiry. The data was analyzed from both normative and emic perspectives. The findings suggest teachers' perceptions of inquiry are confined to traditional views of inquiry across the countries, yet, embedded in the vision of inquiry stated in their curriculum and educational contexts. We discuss implications for professional development about inquiry teaching as well as improvement of educational context in each country.

Key words: curriculum, educational contexts, elementary teachers, science inquiry teaching, teachers' conceptions

Introduction

Science inquiry has a long history in the discourse on science education (Dewey, 1900; 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, Collins, Ratcliffe, Millar, & Duschl, 2003; McComas & Olson, 1998). However, 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, Mullis, & Foy, 2008; Mullis, Martin, Olson, Berger, Milne, & Stanco, 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 inquiry science 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.

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, p. 1). The inquiry-based curriculum describes students "as the inquirer" and teacher "as the leader of inquiry" (ibid, p. 1). 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, Tyalor, Gardner, Scotter, Powell, Westbrook, et al., 2006), Problem-based learning, informational technology integration model, and others (e.g., Poon, Lee, Tan, & Lim, 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 (DeBore, 1991; NRC, 1996, 2000; Schwab, 1962). In the 60s' many science curricula were produced through federally funded projects in which inquiry for future scientists were 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, Druker, Garnier, Lemmens, Chen, Kawanaka, 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.

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 do. 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.

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.

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 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.” “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.

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, p. 11) 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 curricula 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-making, 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.

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, Author 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 encompasses 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 arguments, this study assumed that teachers in different nations had developed different ideas about how to teach science inquiry given the different ways inquiry was highlighted in the curriculum and other relevant educational contexts.

Teachers' conceptions of inquiry teaching would, therefore, reflect both national and local educational contexts.

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).

Table 1 here

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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; Author et al., 2005; Nott and Wellington 1995). In this study we used a teaching scenario survey instrument developed by Author 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 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.
To the survey, we added eight Likert-scale items about teachers' perceptions of curriculum emphasis, perceived importance and practice of inquiry teaching, and school contexts.

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 (Author et al., 2008a) and also examining the degree to which teachers' conceptions reflected the recent view of scientific inquiry included in the five features. When we compared survey responses between nations, we used t-test by assigning points to responses (yes-1 point, no-0 point) and codes (number of times mentioned). For the analysis of items with Likert scales, we assigned scores from 1 to 5 and analyzed variances (ANOVA) to compare responses of the three different groups of teachers.

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. We kept codes that covered at least 10% of the total data from each nation and then, we grouped the open-coding results into three categories based on common properties across all data: aspects of inquiry, student-centered and the nature of task (Table 2).

Table 2 here

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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., Author 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 (Author 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).

Findings

We first report on the relevant teaching contexts of the three countries and then the teachers' perceptions of inquiry from the normative perspective and from the teachers' perspectives. In so doing, we compared how the teachers' conceptions of science inquiry in the classroom were similar and different. Due to the small and convenient samples, the comparison was not to generalize but to provide some insight into directions for future research.

1. Inquiry Teaching Context

The teachers of three countries showed different perception about inquiry teaching context such as the accessibilities to resources, teaching environment and curriculum emphasis.

As for the curriculum emphasis, we asked the teachers how much the curriculum or standards emphasized inquiry and how much the textbook or curricular materials they were using highlighted inquiry. There was no significant difference between the Korean and the US teachers' responses. In contrast, the Singaporean teachers perceived that their national science syllabus emphasized inquiry to a much more significant degree ($p=.011$ compared to the US and $p=.027$ compared to the Korean teachers). A total of 94% of the Singaporean teachers answered that their national syllabus emphasized inquiry "to some degree" or "very much" while 77% of the Korean and 60% of the US teachers answered so. The dominant perception of high emphasis of the Singaporean teachers might be because of the drastic increase in inquiry emphasis of the newly revised national science syllabus.

We also asked the teachers how much inquiry was practiced in school classrooms, whether they were practicing science inquiry teaching as much as their beliefs in its importance in science education, and how confident they are in inquiry teaching. The responses of the teachers from different countries were similar in their perceptions of the degree to which inquiry was practiced in the classroom. On average, the teachers answered that inquiry was practiced "a little" when they referred to inquiry practice in schools in general. Regarding their own practice of inquiry, however, the responses were significantly different in which 69% of the Korean teachers perceived that they were teaching inquiry "more" or "much more" than their beliefs in its importance while 12% of the US teachers ($p=.00$) and 3% of the Singaporean teachers ($p=.00$) perceived so. However the Korean teachers' confidence level was lower than the other two countries. Only 37% of Korean teachers said they were confident in inquiry teaching "to some degree" or "very much" while 75% of the Singaporean teachers ($p=.00$) and 65% of the US teachers perceived so ($p=.00$). That is, Korean teachers thought they practiced much inquiry in classroom; however, they are not confident in their inquiry teaching. The Korean teachers seemed to recognize the importance of inquiry teaching and try hard to practice it by themselves with some degree of uncertainty on their practices.

We also examined facilitating and constraining factors on inquiry teaching and the teachers' satisfaction with support for inquiry teaching. Regarding the constraining factors on inquiry practice, the teachers from the three nations responded similarly. Curricular content coverage and standardized tests were also commonly mentioned as constraining factors. As for facilitating factors, they emphasized different aspects. The Korean teachers emphasized teacher's passion and dedication to inquiry practice while the Singaporean teachers mentioned that good teaching resources such as ICT would help their inquiry teaching. Many US teachers pointed out science inquiry kits (e. g. FOSS) as facilitating factors. For school environment, 59% of the Korean teachers said they were satisfied with science teaching facilities while 27% of the Singaporean teachers and 13% the US teachers perceived so. As for inquiry teaching resources, only 21% of the US teachers said it was easy to find inquiry teaching resources while more teachers in Korea (38%) and Singapore (39%) perceived so.

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

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 aspect 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 (Figure 1).

Table 1 here

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 connecting inquiry results to scientific knowledge (EK) and 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 (Author et al., 2008a).

Differences in responses from the teachers in different nations were also found. The US teachers mentioned inquiry questions much more frequently than the others while the Korean and Singaporean teachers mentioned the feature of constructing explanations more frequently than the US teachers. 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 with their dependency on textbooks in classroom teaching. Especially in Korea, same textbook is used throughout the nation and all the contents in the textbook are expected to be covered, so there is little room for formulating scientific questions on their own.

Inquiry lesson elements. While the teachers' scenario responses revealed the 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 in a lesson. 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 EX, their narratives were very similar. It was 53% of lessons described by the Korean and US teachers 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. 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).

3. Features of Classroom Inquiry from Teacher Perspectives

The results from the open coding of scenario responses demonstrated that the teachers characterized inquiry teaching based on not only aspects of inquiry activity (IS, HT, SH, the first cluster in Figure 2) but also how inquiry activity engaged students (SD, ST, SC, the second cluster in Figure 2) and the nature of inquiry tasks (KA, PS, OE, the third cluster in Figure 2).

Figure 2 here

Aspects of inquiry. The analysis of using teachers' language made differences in teacher conceptions apparent. The Korean and Singaporean teachers used terms such as "inquiry skill" and "inquiry process" (IS) a lot in defining inquiry while the US teachers used "hypothesis testing"(HT) as frequently as "inquiry skill" (Figure 2). The social aspect of inquiry was gained minimal attention noted by a term "sharing" (SH).

The Korean and Singaporean teachers' emphasis on inquiry process skills were reflective of their national curricula in which inquiry process skills were highlighted. In particular, the decades of emphasis on inquiry process skills in Korean curriculum might explain the Korean teachers' strongest emphasis on inquiry process skills as defining features of inquiry.

The teachers' responses to scenario items 7 and 10 supported the possible connection between the teachers' conceptions and the curriculum. The two scenaios involved genearating explanations and discussions and had no hands-on aspect explicitly. While few US teachers considered the activities in items 7 and 10 as inquiry (19% and 16% respectively), two thirds or more of the Korean (62% and 69% respectively) and Singaporean teachers (79% and 69% respectively) considered the two scenarios as inquiry. The teachers from the two nations seemed to define inquiry broadly as long as the activities included any inquiry process skills.

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.

Student involvement. The teachers also used student involvement as a defining character of inquiry (Figure 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 US teachers emphasized student self-direction in the process the most while the Korean teachers emphasized student thinking the most.

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 thinking side-by-side. 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, a teacher might have mentioned student self-direction that might mean student thinking and vice versa.

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) (Figure 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. The teachers in all three nations seemed to agree that an inquiry activity might require constructing solutions to problems.

Conclusion and Discussion

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 (Author et al., 2008a). The teachers' focus on the traditional view of inquiry was clearly shown in the analysis from the teachers' emic 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 (EK) and justifications (EC).

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., NRC, 1996; Millar & Osborne, 1998).

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' perception and practice of inquiry would be changed and internalized through professional development program over time to discuss the implication of curriculum reform. The relatively high emphasis of the Korean teachers on the aspect of student thinking as a critical feature of inquiry activities is also noteworthy. There has been criticism on mindless hands-on activities in the US science classrooms (Flick, 1993). In a comparative study of video recorded science lessons (Roth et al., 2006), inquiry activities in the

US middle school science classroom lacked opportunities for students to make sense of phenomena. Highlighting thinking aspect of inquiry as a key inquiry feature would be a way to support teachers in designing mindful and meaningful inquiry activities. However, we need to discuss and refine what would be the specific forms of thinking that students need to develop during their inquiry process.

The US teachers' emphasis on hypothesis testing as a critical aspect of inquiry is worth our attention. The rather simple connections between scientific inquiry questions, hypothesis and prediction suggest another area of professional development. Equating prediction with hypothesis may lead to a misunderstanding of scientific inquiry only for prediction of phenomena. Scientific questions as a testable prediction may provide an image of science as proving or disproving with phenomena. Furthermore, no room for scientific explanation in these simplified version of inquiry may make the exclusion of EK and EC look reasonable to the teachers, which in return would hinder teachers' refining of conceptions of inquiry that include EK and EC as key inquiry features. 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 but for some insight into a way to understand teachers' conceptions of inquiry and a guide for further research. We propose in this paper some content of 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 (Author et al., 2008a) with consideration of elementary school science contents.

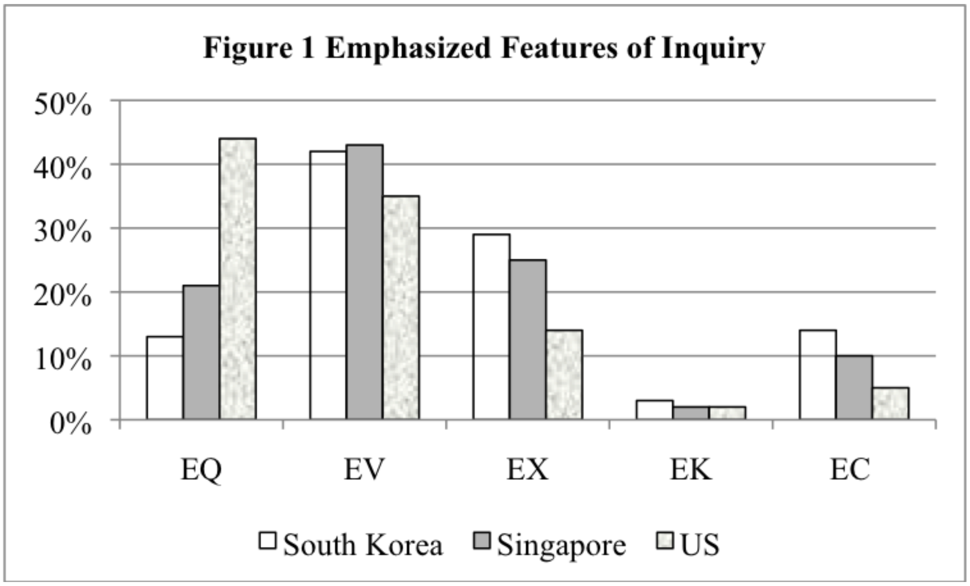
Figure 1 Emphasized Features of Inquiry
50%
40%
30%
20%
10%
0%
EQ
EV
EX
EK
EC
South Korea
Singapore
US

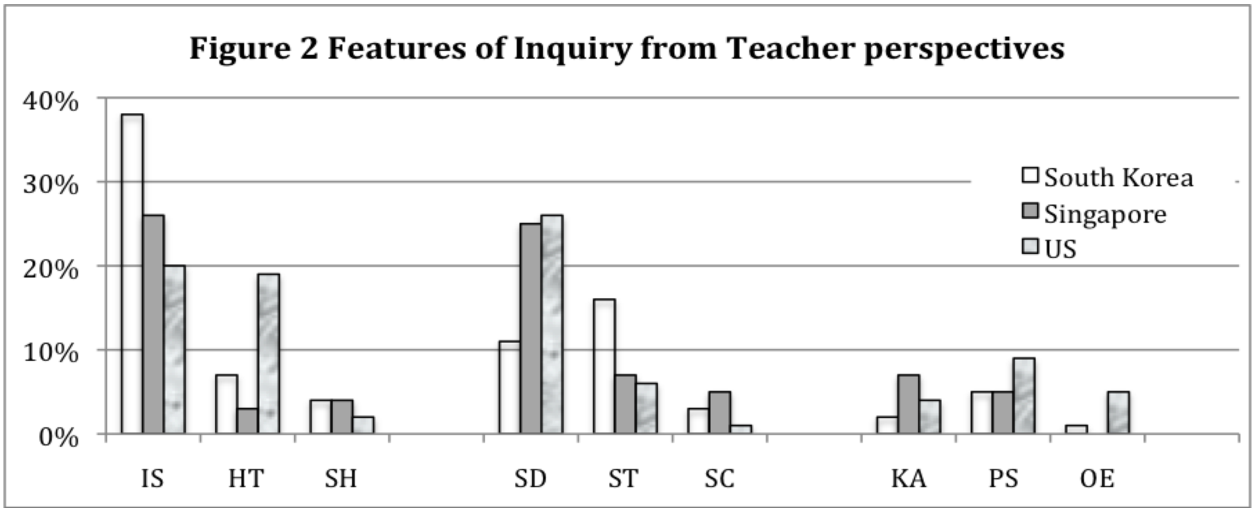
Figure 2 Features of Inquiry from Teacher perspectives
40%
30%
20%
10%
0%
South Korea
Singapore
US
IS
HT
SH
SD
ST
SC
KA
PS
OE

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

Table 2. 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/report 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"