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EXAMINING FACTORS AFFECTING IMPLEMENTATION OF INQUIRY-BASED LEARNING IN FINLAND AND SOUTH KOREA

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Abstract

Using inquiry has become a universal factor in science education, but teachers often face challenges in implementing inquiry-based learning (IBL) because of, for instance, teachers' low confidence in conducting inquiry or insufficient school resources. Much research has been conducted to identify the barriers that impede inquiry practice. However, most studies have employed small-scale qualitative methods from a single-country sample, and, thus, the effects of each factor on conducting inquiry in different educational systems have yet to be measured in one statistical model. Accordingly, this research was aimed to explore the extent to which various teacher- and school-factors have respectively affected teachers' implementation of inquiry-based learning at lower secondary schools. To examine this issue, samples of 496 Finnish teachers in 135 lower secondary schools and 184 Korean teachers in 147 lower secondary schools were selected from the TIMSS 2011 science data set. The findings reveal that teachers' confidence in teaching science and their collaboration to improve science teaching were strongly associated with facilitating inquiry in both countries, and these two factors' positive effects on the implementation were partially derived from inquiry-related professional development in the Finnish sample. In addition, class size and school resources were also significantly related to inquiry practice in Finland, and the teachers' education levels were negatively correlated with the frequency of inquiry practice in Korea. However, in both countries, the teachers' emphasis on exams was indicated as a non-significant factor in predicting inquiry frequency. The results have implications in respect of the roles of professional development and school environment in increasing IBL practice in school science.

Key words: *inquiry-based learning, teacher collaboration, teacher confidence.*

Introduction

Over the past few decades, while an increasing recognition of the importance of scientific knowledge has been indicated, students have presented a decline in the interest in learning science. Since students' interest has been known as a predictor of their academic achievement and further engagement in science, much research has been conducted to identify approaches that increase students' interest. Accordingly, inspiring young learners to engage with inquiry-based learning, which indicates positive effects on improving students' contents knowledge and attitudes towards science and learning science, becomes a long-standing goal of science education (Koksal & Berberoglu, 2012; Sadeh & Zion, 2012; National Research Council [NRC], 2000). Subsequently, much research has shed light on multifaceted pictures of IBL to encourage teachers to implement IBL in school science (Bunterm, Lee, Kong, Srikoon, & Vangpoomyai, 2014; Jocz, Zhai, & Tan, 2014; European Commission [EC], 2007; Lee & Songer, 2003; Yip, 2001). In contrast to the efforts of researchers to disseminate the inquiry practice, however, science teachers continuously hesitate to use scientific inquiry in their classrooms (Trautmann, MaKinster, & Avery, 2004). Through much exploratory research, several factors pertaining to

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the reluctance of teachers to practice inquiry in schools have been revealed; low confidence and competence in using inquiry instructions; lack of time and resources; tight curricula; inadequate professional development; large class sizes, etc. (Ramnarain, 2016; Kikis-Papadakis & Chaimala, 2014; Yoon, Joung, & Kim, 2011; Yeomans, 2011; Harwood, Hansen, & Lotter, 2006; Trautmann et al., 2004; Davis, 2003). Ramnarain (2016), for instance, examined the factors influencing IBL in South Africa and highlighted that a lack of professional science knowledge increased teachers' uncertainty in IBL. Yoon et al (2011) reported that during science inquiry teaching, pre-service teachers had difficulties in developing students' ideas and in designing experiments for students' hypotheses, and they also presented low confidence in science content knowledge. Studies by Kikis-Papadakis and Chaimala (2014) and Davis (2003) argued that insufficient school resources can affect teachers' decisions on conducting IBL. However, even though these previous studies were dedicated to exploring the barriers of inquiry implementation and ascertained a number of factors, each study was conducted with a small number of participants from a single country. In addition, the extent to which those barriers affect teachers' implementation has not been investigated in one statistical model. Hence, in order to construct a more comprehensive understanding of teachers' inquiry practice, this study aimed to investigate how the factors differently affect teachers' implementation of IBL in different countries by using large-scale international assessment data, TIMSS 2011. For two primary reasons, we decided to investigate the samples from Finland and South Korea. Firstly, although they have proven to be top-tier countries in terms of high science achievement, students in both countries present low interest in science and science-related careers (OECD, 2007). Secondly, despite cultural differences in education, teachers in both countries prefer to practice teacher-centered traditional instruction in teaching science (Lavonen & Laaksonen, 2009; Park, Lee, Oliver, & Cramond, 2006). Thus, implementing inquiry in science education is an important matter for the countries, since it is a recognized facilitator in drawing the attention of students towards science, as well as constituting a student-centered approach. Comparing two countries in terms of inquiry implementation would provide some insight for science teachers and teacher educators, policy makers, and school administrators who have faced similar problems in science education and have attempted to increase inquiry practice in schools.

Science Education and Inquiry-based Learning in Finland

Finnish science education has drawn attention from many other countries after its achievements in international assessments, such as PISA (Programme for International Student Assessment) or TIMSS (Trends in International Mathematics and Science Study). The result is often attributed to: 'highly qualified teachers who have autonomy and trust; relatively little standardized testing; collaboration between teachers and schools rather than competition; inclusion and equality rather than elitism; a general belief that education benefits society and the individual' (Curcher & Teras, 2013, p. 61). The Finnish education system offers teachers much freedom in managing classes, curricula, and assessments. In particular, Niemi (2015) emphasizes that, compared with high performing Asian countries, Finnish teachers are free from the pressure of standardized national evaluation. Therefore, teachers are more likely to choose various teaching methods based on students' needs and to use different kinds of assessment tools than other countries with national evaluation systems. For instance, Juuti et al. (2010) reported that there are variety of teaching methods in the education of pre-service science teachers and practiced by in-service science teachers, such as 'teacher-led, large-group lecture or dialog, small-group work, laboratory or practical work, creative problem-solving, reading and writing to learn, and out-of-school informal learning' in Finnish science classes. At the same time, however, teachers are given responsibility in terms of students' learning outcomes and their well-being. Thus, teachers are encouraged to pay attention to students with special needs and to make plans for each student's growth.

In respect of inquiry-based learning, although the Finnish core curriculum does not demand that teachers employ any specific form of instruction, the Finnish educational policy has continuously emphasized inquiry-based science education in the national curriculum of Basic Education (The Finnish National Board of Education, 2014 & 2004). However, many researchers have frequently reported that the culture of inquiry-based science education is underdeveloped as a consequence of the use of more traditional teaching methods, while students want more inquiry-based science education in Finland (Juuti et al., 2010; Lavonen & Laaksonen, 2009; Norris, Asplund, MacDonald, Schostack, & Zamorski, 1996). Beerenwinkel and Börlin (2014) reported that, in comparison studies of physics teaching in Finland, Germany, and Switzerland, they found more teacher-centered interaction than student-centered interaction in Finland, and a higher percentage of teacher-centered interaction was implemented in Finnish classes than in other comparison countries. Juuti et al. (2010) analyzed the responses of 3,626 grade 9 students regarding frequency of teaching methods used in science classes, and concluded that traditional approaches, for instance, solving basic problems, reading textbooks, or conducting practical work, are often used in Finland. Given that traditional teacher-centered science teaching methods have decreased students' interest in science (Avraamidou & Osborne, 2009; EC, 2007) and Finnish students present low interest and negative attitudes toward science and learning science (Martin, Mullis, Foy, & Stanco, 2012; OECD, 2007), inquiry-based science education, which significantly improves students' interest (e.g. Koksal & Berberoglu, 2012; NRC, 2012) has to be given higher priority in teaching science in Finland. However, in accordance with Finnish teachers' evidence-based or research-based teaching practice (Niemi, 2015), more scientific evidence exploring how inquiry-based science education affects students' learning, and identifying the factors that have an effect on conducting inquiry learning in Finland are required in order to increase inquiry-based teaching practice.

Science Education and Inquiry-based Learning in Korea

The Korean educational system including science education is known as highly centralized and controlled by the government in terms of curriculum, teacher training and recruitment, and instructional pace (Im, Yoon, & Cha, 2016; Park, Byun, & Kim, 2011). For instance, according to Im et al. (2016), the government regularly assesses teachers' college programs, based on the education law, to differentiate financial support for each school; prospective teachers have to take regulated, government-run courses to obtain teacher certification; thus, most teacher education institutions offer similar curricula in order to satisfy regulations. Similar to teacher education, curricula for students are also highly regulated by the government. According to Kim and Lavonen (2009), Korean students commence science subjects in the 3^{rd} grade and have to continue studying all four sectors (physics, chemistry, biology and earth science) until lower secondary school. In addition, all science textbooks are reviewed and authorized by the government so that the government can control the science content taught in schools. Moreover, to control the quality of education, the government administers a standard assessment to measure student scholastic achievement from 9^{th} to 11^{th} grade, and the results are reported to schools and parents. In sum, unlike the Finnish education system, Korean science education is highly standardized and centralized.

According to the Ministry of Education [MOE] (2015), the goal of Korean science education is *science for all*, by fostering scientific literacy, acquiring inquiry skills, and considering students' aptitudes for future careers. The core competencies in order to reach this goal are introduced as scientific thought, scientific inquiry skill, scientific problem-solving skill, scientific communication ability, scientific engagement, and lifelong learning. Thus, inquiry-based science education can play a key role in developing these core competencies in science education. However, international assessments have demonstrated that Korean students get less inquiry practice than other participating countries (Martin et al., 2012; OECD, 2007). Thus, in order to increase inquiry practice in science, the MOE revised the curriculum by adding mandatory open inquiry practice for at least six hours per year from 3rd to 10th grade (MOE, 2007). According to the curriculum, the recommendation is for the students themselves to conduct inquiry, from the planning of experiments to the reporting of results, and to collaborate with other pupils at school. The revision has been implemented in primary and secondary schools since 2010, and, subsequently, Park and Lee (2011) explored how it has been implemented at lower secondary schools with 61 science teachers and 1,114 7th graders. They found that, contrary to the government's expectation, teachers determined students' research topics during the first stage, and students often conducted inquiry alone as an out-of-school assignment. The results were likely due to insufficient time, tight curricula, large class sizes, low confidence in teaching and practicing inquiry (Kim, Yoon, Lee, & Cho, 2010; Jhun & Jeon, 2009; Park, 2005). Despite the difficulties, however, students and teachers indicated positive attitudes towards open inquiry (Park & Lee, 2011), and students who experienced open inquiry showed improvement in science process skills (Lee & Lee, 2010).

Nature of Inquiry

In order to understand the obstructions to IBL implementation in school science, it is beneficial to understand the nature of inquiry. IBL refers to the scientist's activities in studying the natural world and to reason based on evidence (NRC, 1996), thus it includes following activities such as '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' (NRC, 1996, p. 23). Through these activities, students can understand both what scientific knowledge is and how it has been produced to date (NRC, 2000). Inasmuch as inquiry is grounded on constructivism, it is less teacher-directed step-by-step instruction, but, rather, a more student-centered way of learning which encourages learners to use their own experiences to construct knowledge (Anderson, 2002). Consequently, compared to the traditional science class, it requires more time to explore and more resources to support individual needs.

In school science, depending on the level of autonomy given to students in designing and conducting the investigation, IBL is divided into three forms: structured, guided, and open inquiry (Koksal & Berberoglu, 2012; Sadeh & Zion, 2011; Zion, Cohen, & Amir, 2007; NRC, 2000). The complexity and uncertainty of teaching and learning increases from structured to open inquiry, but, at the same time, the latter form better reflects the type of authentic, experimental work carried out by scientists (Zion & Mendelovici, 2012). Giving more autonomy to students in conducting experiments does not mean that their learning is independent from teacher intervention, but rather is more dependent on the teacher's ability 'to facilitate the students to raise the appropriate, challenging questions that will guide students during their inquiry process, and trigger student-generated investigation and learning' (p. 384). Hence, in order to conduct inquiry in school, several roles are required of science teachers, such as 'motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, mentor, collaborator, and learner' (Crawford, 2000), and, subsequently, requires teachers to divide their time and efforts between preparing the experiment and its equipment, and answering unpredictable questions from students at different levels.

Emphasis on Assessment

In spite of the abundant roles and responsibilities given to teachers to conduct IBL, they are generally given less autonomy to manage the curriculum, and, consequently, there is insufficient time for teachers to prepare and implement IBL (Yeomans, 2011). Given the fixed curriculum established by the government, teachers consider their principal roles to be maintaining the rigor of the curriculum and transmitting factual knowledge (Trautmann

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et al., 2004), and, thus, teachers may deem IBL to be extra work. This tendency is, in fact, strongly related to high-stakes national and international examinations, which put a high level of pressure on teachers to help students prepare to succeed in exams (Veronesi & Voorst, 2000). For these reasons, teachers tend to avoid time-consuming IBL in spite of students' positive experiences in authentic scientific investigation and its positive impact on students' attitudes and achievements, and to focus more on preparing students for assessments. Hence, it may be assumed that when teachers put more emphasis or value on examinations, as is the case in Korea, they will practice IBL less frequently at school, and that when there is no examination pressure, as is the case in Finland, they will practice IBL regardless of examinations.

Teachers' Professional Development and Confidence

Another impediment to implementing IBL is the insufficient and inadequate professional development (PD) of inquiry pedagogies for pre- and in-service teachers. It is well known that teachers tend to teach their students in ways similar to those they themselves were exposed to as learners (NRC, 1996). However, pre-service teachers are often exposed to teacher-centered, content-based, and 'chalk and talk' instruction during secondary education, and they bring with them their traditional views on learning and teaching science when they enter teacher training college (Seung, Park, & Narayan, 2011; Park, 2005). That is to say, the vast majority of prospective science teachers have rarely experienced authentic scientific inquiry when they start university education and, thus, have misconceptions about inquiry-based teaching (Capps & Crawford, 2013; Yoon et al., 2011; Windschitl, 2000). Consequently, pre-service teachers had significant difficulties in creating research questions, guiding children in designing experiments, and operationalizing variables (Yoon et al., 2011; Roth, 1999). Subsequently, this causes another common hurdle in IBL implementation, where the teacher who lacks scientific inquiry-based research experiences has difficulty in adopting the inquiry pedagogy and in preparing for guiding students in defining research questions, planning experiments, and analyzing data (Yoon et al., 2011; Windschitl, 2003; Singer, Marx, & Krajcik, 2000); that is, a deficiency of inquiry experiences causes low self-confidence in conducting inquiry, and, in turn, misleads pre- and in-service teachers into traditional demonstration-style laboratory exercises with which they are familiar (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009; Trautmann et al., 2004; Davis, 2003).

In order to break this vicious circle, many researchers have focused on revision of professional development for pre- and in-service teachers. Lunsford et al. (2007) reported that, by providing pre-service teachers with basic to complex levels of inquiry, teachers could progressively develop scientific and critical thinking as well as the production skills of complex inscriptions. Riegle-Crumb et al. (2015) revealed that, after participating in Hands on Science (HoS) courses, prospective teachers' attitudes became positive towards inquiry, while the comparison group indicated a decline in favorable attitudes to science. In addition, recent research and projects related with continuous professional development have aimed to develop teachers' cooperation and collaboration by establishing links within and between school networks as well as other local and regional stakeholders (Bolte, Holbrook, Mamlok-Naaman, & Rauch, 2014: Smith, 2014; Snow-Gerono, 2004) so that teachers could be given the chance to work together, share ideas and resources, and reflect on innovative teaching practice in the classes (Loucks-Horsley et al., 2009).

School Resources and Environments

In addition to these teacher-level challenges, school-level impediments to implementing IBL also exist. Kikis-Papadakis and Chaimala (2014) outlined a comparative overview of the challenges to promoting inquiry-based teaching approaches in 13 European educational contexts and indicated that a lack of appropriate teaching resources, such as laboratory or digital resources, were found in some countries, as well as a lack of assessment tools for

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IBL. Dixon (2011), as a chemistry teacher, reported the school-level barriers which prevent the more frequent use of inquiry by teachers in school science. He argued that it is hard for some schools to resource practical investigative science lessons because of a lack of dedicated funding for purchasing certain equipment which can be expensive, a lack of technical support like laboratory technicians, and a lack of specialized laboratory teaching space. Moreover, with respect to manageable class size, classes frequently exceeding 32 students can be a constraint in conducting practical experiments since IBL requires more support for individual needs than traditional laboratory work (Dixon, 2011).

In sum, as described, many factors have affected IBL implementation, not only at teacher-level, e.g. teachers' emphasis on assessment and inappropriate professional development for pre- and in-service teachers, but also at school-level, e.g. scarcity of resources for conducting IBL. However, most of the studies were conducted with small-scale, qualitative data analyses, and did not reveal the extent to which those factors affect teachers' IBL implementation. Thus, this research was aimed to investigate large-scale secondary data, TIMSS 2011, which collected multi-faceted teachers' perspectives in science education as well as their implementation of inquiry in schools, in order to gain a comprehensive understanding of IBL implementation in lower secondary school science by comparing two countries with different educational backgrounds.

Methodology of Research

General Characteristics of Research

In order to conduct the national comparative study between Finland and Korea, samples from TIMSS 2011, one of international large scale assessments, were chosen. With the samples, various factors related to inquiry implementation were examined with a hierarchical multiple regression model. Hierarchical regression is one of the most powerful sets of methods which 'involves theoretically based decisions for how predictors are entered into the analysis' (Petrocelli, 2003).

Data Sample

TIMSS is an international assessment of mathematics and science at the fourth and eighth grades that has been conducted on a four-year cycle since 1995 by the IEA (International Association for the Evaluation of Educational Achievement). This involved sixty-three countries and fourteen benchmarking entities in TIMSS 2011; among them, forty-five countries and fourteen benchmarking entities participated in the eighth grade assessment. The data covers not only students' achievements in mathematics and science, but also students' home environmental background, school resources and climate for teaching, and teacher preparation and instruction (Martin et al., 2012). The samples in this research comprised 624 Finnish science teachers from 152 lower secondary schools and 202 Korean science teachers from 150 lower secondary schools.

Variables

In TIMSS 2011, most of the latent science context questionnaire items were combined into scales constructed by IRT (Item Response Theory) scaling methods using the Rasch partial credit model so that the mean scale score across all TIMSS 2011 participating countries was 10 and the standard deviation was 2 (Martin et al. 2012). Detailed information on each scale used in this study is provided in Appendix 1.

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Dependent Variable

Inquiry-based Teaching Practice: The Teachers Emphasize Science Investigation (ESI) scale was chosen as a dependent variable which represented the frequency of using inquiry in school science measured by teachers' responses to the seven questions such as 'In teaching science to this class, how often do you usually ask students to design or plan experiments or investigations?' or 'In teaching science to this class, how often do you usually ask students to conduct experiments or investigations?'. They were measured using the four-point Likert scale, 'every or almost every lesson', 'about half the lessons', 'some lessons', and 'never' (α=.72).

Teacher-related Factors

Assessment, Professional Development, and Class size: Based on teachers' responses to question 25, 'How much emphasis do you place on national or regional achievement tests to monitor students' progress in science?' the teachers' tendency to prepare students for the assessment was measured. They answered either 'major emphasis', 'some emphasis', or 'little or no emphasis'. Professional development related to IBL was measured with question 28 'In the past two years, have you participated in professional development in improving students' critical thinking or inquiry skills?', and the teacher responded 'yes' or 'no'. Question 12 measured the class size (How many students are in this class?), and teachers wrote down the number of students in their science classes.

Confidence and Collaboration in Teaching Science: Based on teachers' responses to five questions such as 'In teaching science to this class, how confident do you feel explaining science concepts or principles by doing science experiments?' or 'In teaching science to this class, how confident do you feel providing challenging tasks for capable students?', the Confidence in Teaching Science (CTS) scale was measured (α=.73).

The Collaborate to Improve Teaching (CIT) scale was estimated according to teachers' answers to the five statements such as 'Collaborate in planning and preparing instructional materials' or 'Work together to try out new ideas' (α=.81).

School-related Factor

In TIMSS 2011, school principals responded to the school questionnaire on school background. Among them, thirteen questions related to the shortage of general school resources and resources for science instruction were selected and aggregated into the Instruction Affected by Science Resource Shortages (SRS) scale. The scale included statements such as 'How much is your school's capacity to provide instruction affected by a shortage or inadequacy of teachers with a specialization in science?' or 'How much is your school's capacity to provide instruction affected by a shortage or inadequacy of computer software for science instruction?', and principals responded by checking the appropriate box on a four-point Likert scale: 'not at all', 'a little', 'some', and 'a lot' (α=.88).

In addition to these variables, teacher demographics such as gender, educational level, teaching experience, and their major in education and science were included in the model as control variables. As shown in Table 1, we recoded some variables so that the positive scores could indicate a positive relationship with the dependent variable.

Statistical Models and Analysis

Initially, a two-level multilevel model (MLM) was supposed to be employed to examine the effect of teacher and school factors on teachers' IBL implementation in school science since teachers are nested within the schools in large-scale education research as students are nested. However, an Intra-class Correlation Coefficient (ICC) – which is 'the proportion of the total variance in the dependent variable (which is the sum of the between-group variance and the within-group variance) that exists between groups' – smaller than 5% and showing the analysis of clustered data is needless (Bliese, 2000). Hence, instead of MLM, hierarchical multiple regression was employed in this study.

The analysis was conducted using a four-step approach. For the first model (Model 1), teachers' demographics were included to control their background for the coming models. In Model 2 and 3, teacher-level models were built without school-level variables, so that the models can examine the effects of teacher factors on inquiry implementation. Factors such as teachers' emphasis on exam, professional development for inquiry teaching, science class size, and teachers' confidence and collaboration in teaching science were added in the Models. And finally, a full model (Model 4) was constructed by adding a school factor: resources for teaching science. SPSS 22 was used for the hierarchical multiple regression as well as descriptive analysis.

Table 1. Variable coding detail.

Variable Names	TIMSS Coding	Recoding
Teachers Emphasize Science Investigation	TIMSS Scale **(ESI)**	
Emphasis on Exam	1= Major Emphasis 2= Some Emphasis 3= Little or No	1= Some or Major Emphasis 0= Little or No
Professional Development	1= Yes, 2=No	1= Yes, 0= No
Class size	Numeric	
Confidence in Teaching Science	TIMSS Scale **(CTS)**	
Collaborate to Improve Teaching	TIMSS Scale **(CIT)**	
Instruction Affected by Science Resource Shortages	TIMSS Scale **(SRS)**	
Gender	1= Female, 2= Male	0= Female, 1= Male
Educational Level	1= Not Complete ISCED 3 2= ISCED Level 3 3= ISCED Level 4 4= ISCED Level 5B 5= ISCED Level 5A 1st 6= ISCED Level 5A 2nd	
Teaching Experience	Numeric	
Major in Education and Science	1= Science Education & Science 2= Science Education 3= Science 4= Other 5= No formal	1= No formal 2= Other 3= Science 4= Science Education 5= Science Education & Science

Results of Research

Descriptive Results

Table 1 presents descriptive statistics on all factors for both Finnish and Korean teachers including Cohen's d which measures the effect size for the two different groups. Final participant numbers in this study were 496 teachers in 135 schools in Finland, and 184 teachers in 147 schools in Korea after conducting list-wise deletion. In terms of IBL implementation, Korean teachers emphasize science investigation more than Finnish teachers even though the effect size was statistically not significant. Teachers in both countries have been teaching for about 15 years and there were more female teachers than male teachers in lower secondary schools. The educational level of Finnish teachers was significantly higher than Korean teachers (specifically, 87.5% Master and 10.3% Bachelor's degree in Finland, and 34.2% Master and 65.8% Bachelor's degree in Korea). Even though the relatedness of Korean teachers' major in teaching science was higher than Finnish teachers, both of them majored mostly in science alone, not in science education (specifically, 65.8 % of Korean and 61.7% of Finnish teachers majored in science alone). Significant differences were found in class size, exam emphasis, and PD for IBL between the two countries. Class sizes were twice as large in the Korean science classes as the Finnish ones, and Korean teachers focused more on exams than Finnish teachers. While Korean teachers participated much more in PD for IBL than the Finnish teachers, their confidence in teaching science was lower than for the Finnish teachers. Collaboration in teaching science and school resources were higher in Korean schools than Finnish schools. Considering the score of 10 in the TIMSS-scaled items as a mean score derived from all participating countries, both countries showed a higher level in school resources, but lower levels in emphasis on investigation, confidence and collaboration in teaching science than other countries.

Table 2. Descriptive results for Finnish and Korean teachers

	Finland		Korea		
Variables	N	Mean (S.D.)	N	Mean (S.D.)	*d* [b]
Emphasis on Science Investigation [a]	496	9.41 (1.80)	184	9.62 (1.53)	.13
Teaching Experience	496	15.91 (10.07)	184	14.75 (10.28)	-.11
Gender	496	.39 (.49)	184	0.32 (.47)	-.15
Educational Level	496	5.83 (.58)	184	5.34 (.48)	-.92
Major in Education and Science	496	2.92 (.81)	184	3.52 (.88)	.71
Class size	496	15.5 (5.60)	184	34.05 (6.40)	3.08
Emphasis on Exam	496	.28 (.45)	184	.74 (.44)	1.03
Professional development for IBL	496	.08 (.27)	184	.46 (.50)	.95
Confidence in Teaching Science [a]	496	9.10 (2.06)	184	8.49 (2.16)	-.29
Collaboration to Improve Teaching [a]	496	9.37 (1.90)	184	9.67 (1.83)	.16
School Resources for Science Education [a]	135	10.65 (1.23)	147	11.64 (2.06)	.58

a=TIMSS Scale
b= Cohen's *d*: No effect ($d < .2$). Small effect ($.2 < d < .5$), Moderate effect ($.5 < d < .8$), Large effect ($d > .8$)

Hierarchical Multiple Regression

Results from all Finnish models in Table 3 show that teachers' backgrounds, such as their teaching experience, gender, educational level, and major in science have non-significant association with IBL implementation, thus these factors did not affect the frequency of inquiry practice in Finnish secondary schools. On the other hand, as shown in Table 4, the Korean teachers' education level is significantly negatively related to IBL implementation. This means that teachers who have a Master's degree implemented IBL less often than teachers who have a Bachelor's degree in Korea.

As for the effect of class size, this negatively contributed to teachers' inquiry implementation as shown in Finnish Model 2 to 4; thus where there were more students in the class, there were fewer incidences of inquiry practices in Finland. Moreover, its effect was statistically not significant in terms of teachers' IBL frequency in all Korean models.

In Finnish Models 2 and 3, the effect of PD on IBL was reduced and became non-significant when factors for teachers' confidence and collaboration in teaching science were taken into account. This means that a substantial part of the effect of PD on IBL was mediated by teachers' confidence and collaboration. Hence, it may be assumed that the Finnish PD program was so successfully conducted in terms of promoting teachers' confidence and collaboration in teaching science that they have implemented more IBL in school science. Likewise, the effect of PD was also reduced after considering teachers' confidence and collaboration factors in the Korean models, but was statistically so non-significant that it is not possible to conclude that the PD program successfully influenced teachers' confidence or collaboration in teaching science as well as their implementation inquiry in Korea.

Table 3. Effects of factors on teachers' IBL implementation in Finland.

	Model 1		Model 2		Model 3		Model 4	
	β	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Intercept	***9.97	11.64	***10.25	11.97	***6.24	6.68	***4.09	3.68
Teaching Experience	-.021	-.46	-.021	-.48	-.04	-.86	-.03	-.76
Gender	.00	.05	.01	.12	-.03	-.74	-.03	-.80
Educational Level	.00	-.10	.01	.20	.00	.05	.00	.10
Major in Education and Science	-.07	-1.38	-.06	-1.20	-.07	-1.63	-.06	-1.39
Class size			**-.15	-3.17	**-.12	-2.80	**-.14	-3.28
Emphasis on Exam			.07	1.44	.06	1.49	.07	1.65
Professional Development			*.11	2.37	.06	1.35	.06	1.35
Confidence in Teaching Science					***.28	6.60	***.26	6.25
Collaboration to Improve Teaching					***.23	5.41	***.23	5.40
School Resources for Science Education							**.14	3.47
R^2	.005		.042		.181		.201	
ΔR^2			.037		.139		.020	
df	491		488		486		485	
F	.616		***3.087		***11.949		***12.2	

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

In both countries, confidence in teaching science was the most positive indicator for implementing IBL in school science, and the effect persists after controlling for all teacher factors and school factors in the final model. In addition, collaboration for improving science teaching also indicated a strong positive effect on IBL implementation in Models 3 and 4 in both countries. While the collaboration frequency was higher in Korea (see Table 2), the effect of collaboration on IBL was higher in Finland.

Regarding school resources for science education, this was significantly related to IBL practice in Finland, whereas this was not the case in Korea. This means that when there were more resources, there was more incidence of inquiry practice in Finland, but the Korean teachers' implementation of IBL was not related to school resources.

The models were gradually improved after adding more variables, and the final model explained 20% overall variability for the Finnish sample and 18% for the Korean sample. We could not find any issues with correlations and collinearities between variables in all models both in Finland and Korea.

Table 4. Effects of factors on teachers' IBL implementation in Korea.

	Model 1		Model 2		Model 3		Model 4	
	β	t	*β*	t	*β*	t	*β*	t
Intercept	***13.19	9.88	***12.78	8.25	***9.11	5.54	***8.68	4.90
Teaching Experience	.05	.66	.05	.62	.01	.20	.02	.24
Gender	-.04	-.54	-.05	-.66	-.04	-.56	-.04	-.52
Educational Level	*-.21	-2.88	*-.21	-2.76	*-.18	-2.49	*-.17	-2.46
Major in Education and Science	.01	.07	.01	.12	.01	.17	.01	.19
Class size			.01	.10	.02	.27	.02	.28
Emphasis on Exam			.01	.19	.02	.29	.02	.31
Professional development			.12	1.60	.08	1.16	.08	1.16
Confidence in Teaching Science					***.27	3.91	***.27	3.89
Collaboration to Improve Teaching					*.18	2.56	*.19	2.59
School Resources for Science Education							.05	.66
R^2	.047		.062		.180		.182	
ΔR^2			.014		.118		.002	
df	179		176		174		173	
F	2.232		1.655		***4.235		***3.843	

* $p < .05$, ** $p < .01$, *** $p < .001$

Discussion

The aim of this research was to examine factors that affect IBL implementation in lower secondary school and to measure the extent to which those factors affect IBL practice in two different countries, Finland and Korea, based on the TIMSS 2011 science data set. The results of multiple regression found several factors related to inquiry implementation in science education.

This research found that IBL implementation in lower secondary schools can be strongly predicted by teachers' confidence in teaching science. Since many teachers have few learning experiences of inquiry in their school years (Capps & Crawford, 2013; Park, 2005; Windschitl, 2000), determination on the part of teachers to explore a new way of teaching, as well as confidence in their capabilities is required in order to successfully conduct inquiry. Therefore, our results may indicate that when teachers had more confidence in their abilities in teaching science, including inquiry skills, there was a higher frequency of inquiry in school science. This result is in line with previous studies demonstrating that teachers' school practices depend mostly on their beliefs and confidence levels (Davis, 2003; Loucks-Horsley et al., 2003). However, our results also show that both Finnish and Korean teachers presented lower confidence in teaching science than average OECD countries, and, thus, this is likely to cause low frequency of inquiry practice in both countries. Moreover, as Table 5 indicates, among five confidence-related scales, their lower confidence was for different reasons. Consequently, with respect to increasing teachers' confidence, we argue that each educational system needs different support mechanisms.

Table 5. Average of teachers' confidence scale in teaching science.

Confidence scale	Finland	Korea
1) Answer students' questions about science	1.33	1.44
2) Explain science concepts or principles by doing science experiments	1.36	1.41
3) Provide challenging tasks for capable students	1.58	1.78
4) Adapt my teaching to engage students' interest	1.62	1.63
5) Help students appreciate the value of learning science	1.54	1.64

* Teachers chose from: 1. very confident 2. somewhat confident 3. not confident

In addition to teachers' confidence, their collaboration on improving science teaching also presented as a strong predictor for promoting IBL implementation in both Finland and Korea. The result is consistent with previous research (Bolte et al., 2014: Snow-Gerono, 2004) indicating that when teachers had more opportunities to collaborate with each other they tried more inquiry-based teaching in the classroom. When teachers try to use new ways of teaching they usually face a lack of teaching resources, such as lesson plans or instructional materials, to initiate and implement (Dixon, 2011). Accordingly, teachers' co-work or networks can provide them with chances to plan and prepare instructions together so as to produce more adequate materials than with individual preparation and encourage each other to try out new ideas. Moreover, they could learn from each other by reflecting and sharing what they learn from their experiences. Kim (2009) also reported that Korean science teachers have recognized the importance of collaboration with other teachers, so they build teacher communities or teacher interest groups outside of school and seek governmental support to enhance these inter-school collaborations to develop science teaching. Hence, the results demand that teacher educators focus more on how to improve pre- and in-service teachers' confidence and collaboration in conducting inquiry in schools through teaching programs in order to make widespread inquiry teaching possible (Riegle-Crumb et al., 2015; Smith, 2013).

Interestingly, the results showed that the positive effect of confidence and collaboration towards IBL implementation was partially derived from the professional development of IBL in the Finnish sample. Therefore, the results may be interpreted as indicating that inquiry-related PD programs in Finland were likely to increase teachers' confidence and collaboration, and, thus, teachers who participated in the programs implemented more frequent inquiry than teachers who did not participate in the programs. Smith (2013) similarly found that in successful collaborative professional development programs, teachers' confidence and competence in teaching science as well as pupils' attitudes towards learning science were substantially increased. However, in the Korean sample, even though the mediated effect was similarly indicated, it was statistically not significant so we were unable to conclude that inquiry-related PD was successfully conducted in Korea. Regarding the fact that Korean teachers participated in inquiry-related PD much more than Finnish teachers, but its effect on implementing IBL was non-significant, programs must be re-evaluated and modified in order to offer teachers better support (Guskey & Yoon, 2009; Guskey. 2003). In fact, problems related to professional development programs in Korea, including the disconnectedness of programs with school practice, institution-centered training, teachers' low motivation and satisfaction, and unsystematic management, have often been reported (Kim, 2009; Kim, 2007). Further, our results bring the effects of this into question, since, as Murphy, Beggs, and Russell (2005) have argued; only high-quality PD is the key to improving teachers' confidence in science teaching.

Moreover, class size and school resources were indicated as barriers to implementing IBL in Finland, but no relationship was found in the Korean sample. As Dixon (2011) argues, class size over 32 can be a constraint for practical experiments. However, in Korea, the average class size was 34 in the study, which is higher than in Dixon's assertion, thus the number of students in the class probably became statistically not significant in the models. On the other hand, the Finnish sample showed that the average class size was 15.5 and the implementation of IBL was negatively affected by the number of students. In addition to class size, school resources for science instruction were positively related to teachers' inquiry implementation in the Finnish sample. Therefore, Finnish policy makers and educators have to consider how to manage class sizes and school resources if they want to increase emphasis on scientific inquiry at school. Without ensuring the correct number of students per class and level of school resources in one school, inquiry will be practiced less frequently in Finland.

Unlike in the Finnish sample, when the Korean teachers had a higher education level, they conducted less inquiry-based teaching, and, surprisingly, the effect size of their negative relationship (-2.46) was similar to the positive effect of the impact of teachers' collaboration on inquiry practice (2.59) (See Table 4). In terms of the Master programs for teacher education in Korea, which are designed to enhance teachers' pedagogical skills and disseminate new teaching approaches, this seems incomprehensible. However, as shown in Table 6, among the Korean teachers with Master's degrees, teachers who majored in only science comprised a large proportion of the sample (45) and indicated the lowest level of inquiry implementation (8.99). Thus, in turn, they brought down the overall average of IBL implementation among teachers with Master's degrees. One possible interpretation of this result is that since teachers only majoring in science, but not in science education, are likely to study only content knowledge, but not pedagogical content knowledge, they will have lower confidence in teaching science and less collaboration with other teachers than teachers majoring both in science and science education, and, finally, will tend to try inquiry-based teaching less frequently (see Table 6). Therefore, in order to extend IBL in Korean secondary schools, inquiry-related pedagogical training is required for teachers who hold Master's degrees, but have never studied science pedagogy. In addition, as is also shown in Table 6, although the number of teachers was small, teachers holding only science education degrees, but not science, indicated the lowest confidence in teaching science. We assume, conversely, that this resulted from their lack of science content knowledge. Therefore, this population also needs to be taken into account in terms of teacher training in developing science content knowledge.

Finally, despite significant differences of teacher emphasis on exams between Finland and Korea, this did not influence IBL implementation in either country. Specifically, Korean teachers' emphasis on assessment was almost three times higher than that of the Finnish teachers, but the frequency of conducting investigation was similar in both countries. On the one hand, the result is in line with Ripley's (2014) assertion that the Korean educational system is based more on competition than the Finnish system. On the other hand, the result conflicts with previous research arguing that the assessment pressure is likely to prevent time-consuming experimental work in school science so that teachers are more likely to transfer knowledge for preparing the assessments (Trautmann et al., 2004: Yeomans, 2011; Veronesi & Voorst, 2000). In spite of the non-relationship between the pressure of evaluation and the frequency of teachers' IBL practice, however, since we did not examine the effects of this pressure on the quality of teachers' IBL practice, further research is needed to investigate the influence of teachers' perceptions of preparing for exams on the quality of IBL practice in Finland and Korea.

Table 6. Inquiry frequency, confidence, and collaboration of Korean teachers with Master's degrees.

Teachers with majors in	N	IBL frequency	Confidence	Collaboration
Science but Not Science Education	45	8.99	8.18	9.26
Science Education but Not Science	3	9.68	6.86	9.54
Science Education and Science	16	9.76	8.72	10.32

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Conclusion and Limitations

In order to explore the factors related to inquiry practice in different cultures, we compared Finland and Korea, and found common and different factors affecting inquiry-based learning in each country. Among several factors, teachers' confidence in teaching science and their collaboration to improve science teaching were revealed as common and strong predictors for implementing inquiry in both countries. In general, teachers' confidence in teaching science has been emphasized because of its positive effect on student achievement and motivation. In addition to this effect, we add further evidence to justify teacher educators giving higher priority to teachers' confidence in their teacher training programs that aim to increase inquiry practice. However, since Finland and Korea are quite different countries, each population has different practices and cultural backgrounds, and, thus, might indicate different needs in terms of teacher training. Therefore, we encourage comparative analysis of each sample from TIMSS with other cultural backgrounds respectively in advance of developing PD programs. In addition to teacher confidence, teachers' communities for collaboration on developing teaching practice can play an import role in increasing inquiry-based science education, due to the associated demands of creating teaching materials and curricula, and reflecting personal practice. Thus, in order to encourage teachers to engage in consistent inquiry practice, a sustainable environment for teachers within which they can cooperate and collaborate in and out of school is required.

These findings are not without limitations. Since TIMSS 2011 was based on and more concerned with participating students as opposed to teachers, while the TIMSS 2011 student samples are representative of the populations of their countries of origin, the samples of teachers are not representative of the population of their countries of origin. In addition, because only a small number of teachers from each school were involved, usually two or three teachers from each school, the cluster effect was not apparent in the study. Therefore, in terms of further research, we suggest designing a survey, for instance, by using stratified and cluster sampling for teachers, as TIMSS has done for students, so that teacher samples can be representative of populations and show a cluster effect.

References

Anderson, R. (2002). Reforming science teaching: What research says about inquiry? *Journal of Science Teacher Education, 13* (1), 1–12.

Avraamidou, L., & Osborne, J. (2009). The role of narrative in communicating science. *International Journal of Science Education, 31*, 1683–1707.

Beerenwinkel, A., & Börlin, J. (2014). Surface level: Teaching time, lesson phases and types of interaction. In Fischer, H., Labudde, P., Neumann, K., & Viiri, J. (Eds.), *Quality of Instruction in Physics.* (pp. 65-79). Waxmann.

Bliese, P. D. (2000). Within-group agreement, non-independence, and reliability: Implications for data aggregation and analysis. In K. J. Klein, & S. W. J. Kozlowski (Eds.), *Multi-level theory, research and methods in organizations: Foundations, extensions, and new directions* (pp. 349–381). San Francisco, CA: Jossey-Bass.

Bolte, C., Holbrook, J., Mamlok-Naaman, R., & Rauch, F. (2014). *Science teachers' continuous professional development in Europe. Case studies from the PROFILES project*. Berlin: Freie Universität Berlin. Germany / Klagenfurt: Alpen-Adria-Universität Klagenfurt. Austria.

Bunterm, T., Lee, K., Kong, J., Srikoon, S., & Vangpoomyai, P. (2014). Do different levels of inquiry lead to different learning outcomes? A comparison between guided and structured inquiry. *International Journal of Science Education, 36* (12), 1937-1959.

Capps, D., & Crawford, B. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*, 497-526.

Crawford, B. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37* (9), 916-937.

PROBLEMS
OF EDUCATION
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Volume 74, 2016

Curcher, M., & Teras, H. M. (2013). Authentic education: lessons from an online Finnish teacher development Program for 21st century faculty. *E-Learn 2013-World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* (pp. 60-65). Chesapeake, United States: Association for the Advancement of Computing in Education (AACE).

Davis, K. (2003). "Change is hard": What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education, 87* (1), 3-30.

Dixon, N. (2011). For teachers, there is a rhetoric and a reality to scientific inquiry. In Yeomans, E (Eds.), *Perspectives on education: Inquiry-based learning* (pp. 16-19). Wellcome Trust. UK.

European Commission. (2007). *Science education now: A renewed pedagogy for the future of Europe*. Report by a High Level Group on Science Education. Brussels: EC.

Guskey, T. R. (2003). What makes professional development effective? *Phi delta kappan, 84* (10), 748–750.

Guskey, T. R., & Yoon, K. S. (2009). What works in professional development? *Phi delta kappan*, *90* (7), 495-500.

Harwood, W., Hansen, J., & Lotter, C. (2006). Measuring teacher beliefs about inquiry: The development of a blended qualitative/quantitative instrument. *Journal of Science Education and Technology, 15* (1), 69-79.

Im, S., Yoon, H, & Cha, J. (2016). Pre-service science teacher education system in South Korea: Prospects and Challenges. *Eurasia Journal of Mathematics, Science & Technology Education, 12* (7), 1863-1880.

Jhun, Y., & Jeon, M. (2009). The difficulty that is caused open inquiry instruction. *The Journal of Korea Elementary Education, 20* (1), 105-115. [KOR]

Jocz, J., Zhai, J., & Tan, A. (2014). Inquiry learning in the Singaporean context: Factors affecting student interest in school science, *International Journal of Science Education, 36* (15), 2596-2618.

Juuti, K., Lavonen, J., Uitto, A., Byman, R., & Meisalo, V. (2010). Science teaching methods preferred by grade 9 students in Finland. *International Journal of Science and Mathematics Education, 8*, 611-632.

Kikis-Papadakis, K., & Chaimala, F. (2014). *Policy brief on the state-of-affairs on inquiry based learning & the world of work in 13 European educational contexts: Insights from a comparative overview*. MASCIL FP7 Project Report.

Kim, H., Yoon, H., Lee, K., & Cho, H. (2010). Secondary science teachers' perception of 'free inquiry' of the 2007 revised science curriculum. *Secondary Education Research, 58* (3), 213-235. [KOR]

Kim, M., & Lavonen, J. (2009). Experts' opinions on the high achievement of scientific literacy in PISA 2003: A Comparative study in Finland and Korea. *Eurasia Journal of Mathematics, Science & Technology Education, 5* (4), 379-393.

Kim, C. J. (2009). In-service education and development of professional teaching ability. *The SNU Journal of Education Research and Practice, 75*, 67-90. [KOR]

Kim, B. C. (2007). Direction of improvement of professional development and remaining issues. *The Symposium of Korean Society for the Study of Teacher Education, 11*, 105-130. [KOR]

Koksal, E., & Berberoglu, G. (2012). The Effect of guided- inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education, 36* (1), 66-78, DOI: 10.1080/09500693.2012.721942

Lavonen, J., & Laaksonen, S. (2009). Context of teaching and learning school science in Finland: Reflections on PISA 2006 results. *Journal of Research in Science Teaching, 46* (8), 922-944.

Lee, H., & Lee, J. (2010). The Effect of the specific open-inquiry lesson on the elementary student's science-related attitude, science process skill and the instructing teachers' cognition about open-inquiry. *Journal of Science Education 34* (2), 405-428. [KOR]

Lee, H., & Songer, N. (2003). Making authentic science accessible to students. *International Journal of Science Education, 25* (8), 923-948.

Loucks-Horsley, S., Stiles, K. E., Mundry, S. E., Love, N. B., & Hewson, P. W. (2009). *Designing professional development for teachers of science and mathematics*. Thousand Oaks: Corwin.

Lunsford, E., Melear, C. T., Roth, W.-M., Perkins, M. & Hickok, L. G. (2007). Proliferation of inscriptions and transformations among pre-service science teachers engaged in authentic science. *Journal of Research in Science Teaching, 44* (4), 538-564.

Martin, M. O., Mullis, I. V. S., Foy, P., & Stanco, G. M. (2012). *TIMSS 2011 International Results in Science*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Ministry of Education [MOE] (2015). *2015 National Curriculum Revision*. [KOR]

Ministry of Education [MOE] (2007). *Science Education Curriculum*. [KOR]

Murphy, C., Beggs, J., & Russell, H. (2005). *Primary horizons: starting out in science*. London: Wellcome Trust.

National Research Council. (1996). *The National Science Education Standards*. Washington. DC: The National Academies Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. (2012). *A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards*. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Niemi, H. (2015). Teacher professional development in Finland: Towards a more holistic approach. *Psychology, Society and Education, 7* (3), 278-294.

Norris, N., Asplund, R., MacDonald, B., Schostack, J., & Zamorski, B. (1996). *An independent evaluation of comprehensive curriculum reform in Finland*. Helsinki: National Board of Education.

OECD (2007). *PISA 2006: Science Competencies for Tomorrow's World*, Volume 1.

Park, H., Byun, S., & Kim, K. (2011). Parental involvement and students' cognitive outcomes in Korea: Focusing on private tutoring. *Sociology of Education, 84* (1), 3-22.

Park, J., & Lee, K. (2011). Actual conditions of free inquiry implementation and the perceptions of teachers and students in middle school science. *Journal of Research in Curriculum & Instruction, 15* (3), 603-632. [KOR]

Park, S., Lee, S., Oliver, J. S., & Cramond, B. (2006). Changes in Korean science teachers' perceptions of creativity and science teaching after participating in an overseas professional development program. *Journal of Science Teacher Education, 17* (1), 37-64.

Park, H. J. (2005). Induction secondary science teachers` conceptions of teaching science and their effort for professional development. *Journal of The Korean Association for Science Education, 25* (3), 421-430.

Petrocelli, J. (2003). Hierarchical multiple regression in counseling research: Common problems and possible remedies. *Measurement and Evaluation in Counseling and Development, 36* (9), 9-21.

Ramnarain, U. (2016). Understanding the influence of intrinsic and extrinsic factors on inquiry-based science education at township schools in South Africa. *Journal of Research in Science Teaching, 53*, 598–619.

Riegle-Crumb, C., Morton, K., Moore, C., Chimonidou, A., Labrake, C., & Kopp, S. (2015). Do inquiring minds have positive attitudes? The science education of preservice elementary teachers. *Science Education, 99* (5), 819-836.

Ripley, A. (2014). *The smartest kids in the world: And how they got that way*. Simon & Schuster Paperbacks.

Roth, W. (1999). Scientific research expertise from middle school to professional practice. *Paper presented at the Annual Meeting of the American Educational Research Association*, Montreal, Quebec.

Sadeh, I., & Zion, M. (2012). Which type of inquiry project do high school biology students prefer: open or guided? *Research in Science Education, 42* (5), 831-848.

Seung, E., Park, S., & Narayan, R. (2011). Exploring elementary pre-service teachers' beliefs about science teaching and learning as revealed in their metaphor writing. *Journal of Science Teacher Education, 20,* 703-714.

Singer, J., Marx, R., & Krajcik, J. (2000). Constructing extended inquiry projects: Curriculum materials for science education reform. *Educational Psychologist, 35* (3), 165-178.

Smith, G. (2013). An innovative model of professional development to enhance the teaching and learning of primary science in Irish schools. *Professional Development in Education, 40* (3), 467-487.

Smith, G. (2014). The impact of a professional development programme on primary teachers' classroom practice and pupils' attitudes to science. *Research in Science Education, 45*, 215-239.

Snow-Gerono, J. L. (2004). Professional development in a culture of inquiry: PDS teachers identify the benefits of professional learning communities. *Teaching and Teacher Education, 21*, 241-256.

The Finnish National Board of Education. (2014). *Core curriculum for basic education 2014*. [FIN]

The Finnish National Board of Education. (2004). *Core curriculum for basic education 2004*. [FIN]

Trautmann, N., MaKinster, J., & Avery, L. (2004). What makes inquiry so hard? (and why is it worth it?). *Proceedings of the National Association for Research in Science Teaching (NARST) 2004 Annual Meeting.* Vancouver, BC, Canada.

Veronesi, P., & Voorst, C. (2000). Science teacher beliefs: Toward an understanding of state science exams and their influence on teacher beliefs. *Paper presented at the 2000 Annual International Conference of the Association for the Education of Teachers in Science*, Akron, Ohio.

Windschitl, M. (2000). An analysis of preservice science teachers' open inquiry experiences. *Paper presented at the annual conference of the American Educational Research Association Conference*, New Orleans, LA.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education, 87* (1), 112-143.

Yeomans, E. (2011). *Perspectives on Education: Inquiry-based Learning*. Wellcome Trust. UK.

Yip, Y. (2001). Which came first, the chicken or its egg? An inquiry based activity. *School Science Review, 82* (300), 109-114.

Yoon, H., Joung, Y., & Kim, M. (2011). The Challenges of science inquiry teaching for pre-service teachers in elementary classrooms: Difficulties on and under the scene. *Research in Science Education, 42,* 589-608.

Zion, M., Cohen, S., & Amir, R. (2007). The spectrum of dynamic inquiry teaching practices. *Research in Science Education, 37* (4), 423-447.

Zion, M., & Mendelovici, R. (2012). Moving from structured to open inquiry: Challenges and limits. *Science Education International, 23* (4), 383-399.

Appendix 1. Scaled Items in TIMSS 2011 Teacher and School Questionnaires

Teacher Questionnaire

The Collaborate to Improve Teaching (CIT) Scale

Q10. How often do you have the following types of interactions with other teachers?

(Daily or almost daily, 1-3 times per week, 2 or 3 times per month, Never or almost never)

1) Discuss how to teach a particular topic
2) Collaborate in planning and preparing instructional materials
3) Share what I have learned about my teaching experiences
4) Visit another classroom to learn more about teaching
5) Work together to try out new ideas

The Confidence in Teaching Science (CTS) Scale

Q18. In teaching science to this class, how confident do you feel to do the following?

(Very Confident, Somewhat Confident, Not Confident)

1) Answer students' questions about science
2) Explain science concepts or principles by doing science experiments
3) Provide challenging tasks for capable students
4) Adapt my teaching to engage students' interest
5) Help students appreciate the value of learning science

The Teachers Emphasize Science Investigation (ESI) Scale

Q19. In teaching science to the students in this class, how often do you usually ask them to do the following?

(Every or almost every lesson, About half the lessons, Some lessons, Never)

1) Observe natural phenomena and describe what they see
2) Watch me demonstrate an experiment or investigation
3) Design or plan experiments or investigations
4) Conduct experiments or investigations
5) Use scientific formulas and laws to solve routine problems
6) Give explanations about something they are studying
7) Relate what they are learning in science to their daily lives

School Questionnaire

The Instruction Affected by Science Resource Shortages (SRS) Scale

Q9. How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the following?

(Not at all, A little, Some, A lot)

A. General School Resources

1) Instructional materials (e.g., textbooks)
2) Supplies (e.g., papers, pencils)
3) School buildings and grounds
4) Heating/cooling and lighting systems
5) Instructional space (e.g., classrooms)
6) Technologically competent staff

B. Resources for Science Instruction

1) Teachers with a specialization in science
2) Computers for science instruction
3) Computer software for science instruction
4) Library materials relevant to science instruction
5) Audio-visual resources for science instruction
6) Calculators for science instruction
7) Science equipment and materials

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