This dissertation investigates the effect of inquiry-based science education on Finnish students' attitude and performance based on international large-scale assessments. In addition, it tackles the issues relating to Finnish teachers' implementation of inquiry. The results indicate that guided inquiry experiences increase students' cognitive and non-cognitive factors including future career aspirations. Also, teachers' inquiry implementation is highly correlated to their confidence and collaboration.
IMPLEMENTATION AND IMPLICATION OF INQUIRY-BASED SCIENCE EDUCATION IN THE FINNISH CONTEXT

EVIDENCE FROM INTERNATIONAL LARGE-SCALE ASSESSMENTS: PISA AND TIMSS
Jingoo Kang

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ABSTRACT

The students’ negative trend of science-related affect during secondary school has been revealed widely in the world according to the reports from international large-scale assessments such as PISA or TIMSS. Especially, Finnish students have indicated a contradicting phenomenon that although they have been located as one of the top performers, their interest has deteriorated continuously for last decade. Therefore, this dissertation tries to tackle the question “how to increase students’ attitude on science and science careers?” by means of inquiry-based learning in the Finnish context. In addition, in order to support teachers’ inquiry implementation, it aims to examine factors affecting teachers’ inquiry practice. With these aims, three original empirical studies were conducted based on the Finnish samples from PISA 2006, TIMSS 2011, and PISA 2015.

In the first study, the factors relating to student-centered approaches were examined by exploratory and confirmatory factor analyses from PISA 2006 data, and two inquiry-related latent variables, guided inquiry and open inquiry, were found in the Finnish context. Then, these latent variables were explored by structural equation modeling in order to investigate the relationships between inquiry experiences and students’ interest and performance. According to the findings, the guided inquiry was dominantly practiced at school, and this inquiry experience was revealed as a strong positive indicator in predicting students’ performance and interest. On the other hand, the open inquiry was almost never conducted at the school in Finland, and this level of inquiry indicated a strong negative correlation with students’ performance while its relation was statistically non-significant to students’ interest.

Since students’ attitude and learning experience have been considered as important predictors of future career aspiration, in the second study relationships among interest, outcome expectation, self-efficacy and inquiry-based learning experience were rigorously investigated based on the social cognitive career theory. According to the result, although Finnish students indicated a lower level of interest, outcome expectation, self-efficacy and inquiry experience than average OECD countries, correlations among these factors were higher. Regarding career expectation, students’ future career aspirations in science can be promoted by inquiry learning experience in school science for 15-year-old students. Specifically, the proposed model indicated that inquiry learning experiences indirectly increased students’ interest in science career by increasing students’ self-efficacy and outcome expectations. Considering
that the direct effect of inquiry on career aspiration was negative, this study indicates an important implication of designing psychometrics in measuring the correlation.

In the third study, factors triggering or hindering teachers’ inquiry implementation were examined. It was a comparison study between Finland and South Korea in order to investigate common and different traits of each educational system regarding inquiry practice. According to the result regarding Finland, it indicated that the inquiry implementation in lower secondary schools could be strongly predicted by teachers’ confidence in teaching science and their collaboration. Moreover, the results showed that the positive effect of confidence and collaboration towards inquiry implementation was partially derived from the professional development relating to the inquiry. Therefore, the result can be interpreted as inquiry-related professional development in Finland was likely to increase teachers’ confidence and collaboration, and, thus, teachers who participated in the programs implemented more inquiry than those who did not involve in the programs. However, despite the positive effect of the program, the Finnish teachers’ participation rate of the professional development was low. In addition to these factors, a class size and school resources were also significantly related to inquiry practice in Finland. Thus, in order to encourage teachers’ consistent practice of inquiry, comprehensive understanding and investigating the teaching environments should be taken into consideration in designing educational policy. Also, the results strongly support to build a sustainable environment for teachers in cooperating and collaborating each other in and out of school.

**Keywords:** science education, inquiry-based learning, attitudes, learning environment, PISA, TIMSS
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TIIVISTELMÄ


Oppilaiden kiinnostuksen ja oppimiskokemusten on havaittu ennustavan tulevaisuuden ammattipyrimykisiä, joten toisessa osatutkimuksessa selvitettiin kiinnostuksen, suoriutumisodotusten, minäpystyvyyden ja tutkimusten tekemisen kokemusten välistä suhdetta Social Cognitive Career -teorian pohjalta. Suomalaiset oppilaat osoittivat vähäisempää kiinnostusta luonnontieteitä kohtaan kuin OECD maiden oppilaat keskimäärin, suoriutumisen odotukset olivat pienemmät, minäpystyvyys heikompa, ja heillä oli vähemmän kokemuksia tutkimusten teosta. Korrelaatiot näiden edellä mainittujen muuttujien välillä olivat vahvempia. Tutkimustulosten perusteella voidaan sanoa, että oppilaiden hyvät tutkimalla oppimisen kokemukset koulun luonnontieteiden tunneilta voivat edistää 15-vuotiaiden oppilaiden hakeutumista tulevaisuudessa luonnontieteiden aloille. Tutkimuksessa ehdotettu malli osoittaa erityisesti,
että tutkimalla oppimisen kokemukset lisäsivät epäsuorasti oppilaiden kiinnostusta luonnontieteellisiä ammateja kohtaan lisäämällä oppilaiden minäpystyvyyttä ja suo- riutumisodotuksia. Tutkimuksen tulosten mukaan välillisten vaikutusten huomioiminen perinteisen psykometriikan suoran korrelaation tutkimisen sijaan on oleellista, koska tutkimusten tekemisen suora vaikutus ammattipyörykkymksiin oli negatiivinen, vaikka epäsuora vaikutus huomioidien vaikutus oli positiivinen.


Avainsanat: luonnontieteiden opetus ja oppiminen, tutkiva oppiminen, asenteet, oppimisympäristö, PISA, TIMSS
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Jingoo Kang
LIST OF EMPIRICAL STUDIES


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MAIN ABBREVIATIONS AND ACRONYM

CFA Confirmatory Factor Analysis
EFA Exploratory Factor Analysis
HMR Hierarchical Multiple Regression
IBL Inquiry-based Learning
ILSA International Large-scale Assessment
PISA Programme for International Student Assessment
SCA Student-Centered Approach
SEM Structural Equation Modeling
TIMSS Trends in International Mathematics and Science Study
1 INTRODUCTION

In science education, it is an important issue to attain and retain students’ lifelong interest not only for gaining new blood in the field of science but also for growing students as a scientifically literate citizen. The scientifically literate citizen refers to those who are able to use “science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment” and understand “the interrelationships between science, technology and other facets of society, including social and economic development” (NSTA, 1971, pp. 47-48). As socio-scientific issues have been increased, the societal demands of the scientifically literate citizen are increased without a doubt. However, the trends of students’ interest in science have been negative, especially in western countries (OECD, 2016a) that are likely to limit the socio-economic growth of the nations.

Therefore, as an educator and a researcher in science education, how to increase students’ interest may be the long-lasting question, and, likewise, I through this dissertation want to deal with this question with inquiry-based learning in Finnish context based on the international large-scale data, PISA and TIMSS.

Then, why inquiry? Why Finland? Why large-scale data? The keywords of my study may be these three words—inquiry, Finland, and large-scale data. In order to explain the criteria for selecting these keywords, I need to narrate my personal experiences in Finland and South Korea in science teacher education as the starting point and my personal motivation for this study. I have a bachelor’s degree in biology and master’s in biology education achieved in Korean universities. Frankly speaking, however, I was not interested in science at all, but only in education. Specifically, experience in studying biology and biology education at the university level alienated me from science more. At the moment, although I could not figure out what elements affect my interest in science and why it happened to me, I was sure that I would better not to teach students’ without my own interest in science. Thus, I left to find the answer to the question and, by chance, a clue was found by participating one lecture for science student teachers at the University of Eastern Finland.

The lecture was about nature of science focusing on its tentativeness by conducting guided inquiry (definition of guided inquiry is described in Chapter 3). This activity is also known as a mysterious box (Cavallo, 2007). At the beginning of the class, a lecturer gave a small sealed box containing an unknown item to each group of three to four members and asked to find out what it contained without unwrapping the box (It was a Research Question). Since each group was given a different box, the answers about the items should be different (The boxes referred to a Natural Phenomenon). First, the student teachers were asked to guess and report what was in the box by watching, smelling, shaking, or weighting by hands (It was a Hypothesis). Then, there were several measurement tools and instruments to investigate the research question. The student teachers had to decide what and how to measure the substance in the box (It was the Measurement Process). After testing the box with several instruments, they reported to other groups about their results (It was a Drawing and Reporting Conclusions). At the end of the class, however, we were not still allowed to open the box, and the lecturer emphasized that it is the same in a real scientific inquiry that people cannot 100% see the inside of the natural phenomena, but, instead, they guess what may happen by modeling by means of possible measurement tools and following re-
It means the conclusions are likely to be changed by using different methods or advancing measurement skills or a brilliant idea. Thus, through this inquiry process, he wanted to teach the student teachers about the tentativeness of the knowledge of science as one of the features of nature of science. Interestingly, by this guided inquiry experience, I was significantly motivated to engage with further science activities and tackle scientific research questions for other scientific phenomena. I later realized that I was mostly exposed to structured or confirmation inquiry practice in South Korea that is more strict and authoritarian manners in teaching science than guided or open inquiry, and it may decrease my individual curiosity and interest in learning science since types of instruction can hinder or foster the development of science interest (Krapp & Prenzel, 2011).

In addition to this inquiry practice, I participated several types of other inquiry experiments implemented for student teachers in the school and these experiences were quite interesting to me in two aspects that students are allowed to stand against to the authority of science knowledge through the inquiry process, and that different types of inquiry have been put in practice in teacher education in Finland. As is known widely, teachers tend to teach students as they were taught in their school years including teacher education program as a learner (NRC, 1996). Thus, I assumed that this guided inquiry may be dominant or at least often practiced in Finnish science classes at school and that it may increase students’ interest in science. Subsequently, I wanted to explore the questions that what types or levels of inquiry are often implemented in Finland and what effects it gives to the Finnish students. Accordingly, this article-based dissertation aims to shed light on the type of inquiry widely conducted at Finnish lower secondary school and its effect on students’ learning outcomes including cognitive and non-cognitive by analyzing samples representing the Finnish population from the data of PISA and TIMSS. Specifically, three articles unearth two research questions that to what extend inquiry affects students’ learning outcomes including interest, performance, and career aspiration in science, and that what factors affect in implementing inquiry in school science in Finland.

Since the main purpose of this dissertation is to investigate the way to increase students’ interest in science, I begin by describing theories and research related to students’ interest in science and science-related careers in Chapter 2. Next, I describe inquiry-based science education, especially open inquiry and guided inquiry, and its effects on students’ science interest. As part of this, the relationship between inquiry and career aspiration based on social-cognitive career theory (Lent et al. 1994) is explained. In addition, at the end of Chapter 3, factors impeding teachers’ inquiry practice are also briefly introduced in order to discuss how to support and encourage teachers in implementing inquiry at school. I then describe science education in Finland in respect of inquiry-based learning in order to make a connection with previous chapters to the context of Finland in Chapter 4. After this, aims, methods, and results of three studies are described in detail sequentially through Chapter 5 to 7. Finally, significance and implication of the studies and suggestions for further research are discussed in Chapter 8.
In learning such core domains like science, interest has been studied rigorously over the past decades since it is broadly endorsed that interest draws and retains students’ attention on the subject and stimulate their intellectual curiosity consistently. Thus, students who have an interest in learning in certain subjects tend to continue to re-engage and develop more conceptual sophistication (Renninger & Hidi, 2016). In addition, much research has indicated that interest has so highly correlated with students’ future career trajectories that it may be a significant predictor to measure probabilities in selecting a future goal. Thus, as Rogers and Wiggins (2003, p. 109) describes interest “has been used pervasively in many disciplines as a means of explaining concepts as varied as a career choice, motivation, enjoyment, learning and academic achievement, participation, attention, flow, and importance.”

In my studies, science-related interest also has worked a vital role as a mediator between several constructs in explaining relations between students’ learning experience and learning outcomes. In the following section, accordingly, I briefly describe theories and research related to the interest and its various effects, such as, on achievement and career choice in science education. Especially, in order to describe the relations among interest, learning experiences, and career aspiration, Social Cognitive Career Theory (SCCT, Lent et al., 1994) will be introduced in Chapter 3.

2.1 INTEREST IN SCIENCE

Interest has been explained with several theories such as Alexander’s model of domain learning (2004), Silvia’s Psychology of Constructive Capriciousness (2001), or the person-object theory of interest (POI) (e.g., Krapp, 2002) in educational science. A common denominator of them, however, is that interest is content specific. In science education, for instance, the object can refer to a particular science content, subject, area of knowledge, or activity. PISA also refers to the POI theory in their framework that “an interest is always directed towards an object, activity, field of knowledge or goal”, thus “interest in science can be defined generally (interest in science) or specifically (interest in science topics, be it a broader discipline or school subject, such as biology, or a more specific domain or research question, such as bacterial infections)...PISA measures the extent to which students are interested in five broad science topics, or subjects” (OECD, 2016, p. 125).

Regarding a construct of interest, Krapp (2007) describes three general characteristics of the interest construct—cognitive aspects, emotional characteristics, and value-related characteristics. Cognitive aspects refer to the readiness to acquire new knowledge related to the person’s interest and to apply the knowledge in new situations since “a person who is interested in a certain subject area is not content with his or her current level of knowledge or abilities in that interest domain” (Krapp, 2007, p. 10). Thus, “highly interested students are characterized by a comparably differentiated knowledge structure in the corresponding object area” (Krapp & Prenzel, 2011, p. 31). Emotional characteristics refer to positive emotions such as enjoyment connecting with an interest-triggered action or experience that are likely to be stored
and be remembered for a long time since “any interest...is associated with positive experiential states” (Krapp & Prenzel, 2011, p. 31). Also, the emotional experiences are related to “the basic needs of competence, autonomy, and social relatedness” (Krapp, 2007, p. 11). Lastly, the value-related characteristics refer to positive personal evaluation on the object of interest since “a person shows a high subjective esteem for the objects and actions in his or her areas of interest” (p. 11); thus, it has “the quality of personal significance” (p. 11).

Regarding levels of interest, Hidi and Renniger (2006) introduced Four-phase Model characterized by varying amounts of affect, knowledge, and value that are similar to the interest construct of Krapp (2007). The model is composed of triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest. The first two forms of interest (triggered and maintained situational interest) “refer to focused attention and the affective reaction that is triggered at the moment by environmental stimuli, which may or may not last over time” (p. 113) and the latter two forms of interest (emerging and well-developed individual interest) “refer to a person’s relatively enduring predisposition to re-engage particular content over time as well as to the immediate psychological state when this predisposition has been activated” (p.113). The four phases are described as a sequential and cumulative process of interest development since they cannot be progressive without support from others “or because of challenges or opportunities that a person sees in a task” (p.112) in each phase. Although all levels of interest have its own significant role in terms of triggering and developing students’ attention into specific fields, individual interest has been more focused in educational studies than situational interest because of its consistency and significant effect on learning outcomes.

For several reasons, interest is particularly concerned about science education. As is known to all, children show interest in all sorts of things including all natural phenomena. This interest, specifically, interest in science, is fairly stable until they stay and study at primary school. However, negative trends regarding science interest have been continuously indicated during the secondary school period. Krapp and Prenzel (2011) identified three explanations regarding the trend that:

(1) the development of science interest is primarily dependent on the quality and type of instruction:
(2) students in adolescence tend to give priority to the coping with new developmental tasks and are no longer ready to invest all of their energy in academic learning:
(3) young people, when searching for their own identity, subject their abilities and interests to a critical evaluation. All interests which do not seem to be compatible with the ideal self-concept are devalued and excluded from the student’s personally important interest pattern (p. 35).

Therefore, they concluded that the declining interest in science is inevitable consequences during adolescences’ differentiation process of interest.

However, although the negative trends of science interest are likely to be a natural phenomenon during the developmental process of young people, it is indicated that, especially in the western countries, students’ interest in science in the secondary school are decreasing more and more over time, an absolute reduction. Finnish students, for instance, had been marked among the lowest interest group in PISA 2006 while they presented a great achievement in science. In PISA 2015, unfortunately, their interest was decreased more than nine years ago as well as their achievement.
In addition, this trend is more distinctive in rural areas than urban regions in Finland (OECD, 2016a). Therefore, it is not enough to attribute students’ declining interest to their natural developmental process. Rather, in terms of the first explanatory approach of Krapp and Prenzel (2011) that the school instruction matters in science interest, it is rational to focus more on pedagogical approaches practiced in school science such as inquiry-based learning and its effect than on unalterable conditions.

2.2 INTEREST IN SCIENCE CAREER

As part of science interest, students’ career aspiration in STEM (Science, Technology, Engineering, and Math) fields also has been studied rigorously. In general, students are likely to start to think about their future career at the age of 11 or 12 (Nurmi, 2005). Then, this perception on career has been developed during the secondary school year firmly by learning various subjects and participating several activities at and out of school environments since these experiences foster students’ knowledge of professions and give students chances to know their own strength and abilities on the careers (e.g., King & Glackin, 2010; Wang, 2013). Although it is not firmly established in the early age, students’ early career expectation is regarded as an important predictor in anticipating their actual choice in future. Schoon (2001) conducted a longitudinal study with the data collected from the National Child Development Study (NCDS) in 1974 and 1991 from the UK in order to examine factors related to future career choice in science, and he reported that “occupational attainment at age 33 was significantly related to the job aspirations expressed at age 16” (p. 214). Tai et al. (2006) also traced factors related to students’ graduation in science majors in four-year colleges based on the sample from the U.S. National Education Longitudinal Study. According to their results, eighth graders’ aspiration to be involved in science-related occupations at the age of 30 indicated as the most significant predictor in gaining the degree in science.

Given that school-age children’s career expectation plays a pivotal role, it is an important issue to investigate what factors affect on the desires. In line with Krapp and Prenzel’s (2011) explanations on the trend in science interest, students’ career preference can be explained in two ways. First, regarding teaching approaches, students’ science career expectation can be influenced by the type of instructions. For instance, students participated in inquiry-based experiments indicated more interest in science and STEM careers than those who have participated traditional teaching approaches (e.g., Jocz, Zhai, & Tan, 2014; Potvin & Hasni, 2014; Gibson & Chase, 2002). Secondly, regarding students’ evaluation of their own abilities and surrounding environments, students’ career choice may be affected by their self-efficacy or self-concept based on their comparative advantage in terms of academic or physical merits. March and Yeung (1997) supported this perspective that students are likely to distinguish occupations based on their self-regulated perception so as to choose the one which is more successful rather than the unlikely successful one. Indeed, much research support that when students contemplate STEM careers, their subjective belief in one’s ability, self-efficacy belief, influenced academic and career choices (e.g., Zeldin, Britner, & Pajares, 2008).
These two assumptions are compatible in a way that students’ learning experiences may increase students’ self-efficacy or that students’ self-belief may lead students to participate more science activities and to engage in further science learning. Despite the compatibleness of two approaches, however, in education much research supports the first perspective that, for instance, Russell et al. (2007) reported that regardless of students’ majors at the university, which means irrespective of their identified strengths in the past, 68% of participants in hands-on investigation indicated increased interest in science-related careers and 29% of them indicated increased anticipation to obtain Ph.D. in STEM fields. Taskinen et al. (2013) also supported that students’ self-efficacy are aroused from and influenced by science learning in class; in turn, both efficacy and learning experiences finally affect students’ future-oriented motivation to study science. The Social Cognitive Career Theory (SCCT, Lent et al. 1994) framework which is widely accepted in the occupational studies also supports that learning experience plays a pivotal role in increasing self-efficacy so that, in turn, the experience influence on future goals and actions indirectly (see Figure 2). I will discuss about the SCCT in the following chapter which describes the relations of several constructs predicting students’ future goal setting. Therefore, it is desirable for educators to search what kinds of learning experiences are positively related to students’ attitudes such as inquiry-based science education.
3 INQUIRY-BASED SCIENCE EDUCATION

As described in the previous section, inquiry-based learning is likely to indicate multifaceted influences on students’ affect. Indeed, inquiry-based learning has come to a keystone of science education for it fosters students’ understanding of nature of science and scientific inquiry. It requires students to involve at least a basic inquiry cycle such as “asking a simple question, completing an investigation, answering the question, and presenting the results to others.” (NRC, 1996, p. 122). Thus, in science education, inquiry-based learning is understood as “engaging students in experimentation and hands-on activities, and also about challenging students and encouraging them to develop a conceptual understanding of scientific ideas” (OECD, 2016, p. 69); consequently, students who have been involved in inquiry are likely to experience active thinking and responsibility for learning which in turn improve conceptual understanding (Minner, Levy, & Century, 2010). With this perspective, PISA measured students’ inquiry experiences as “the extent to which science teachers encourage students to be deep learners and to enquire about a science problem using scientific methods, including experiments” (OECD, 2016, p. 69).

Although procedures and definitions vary in science education, eight aspects of scientific inquiry have been suggested by Lederman et al. (2014, p. 75).

1. Scientific investigations all begin with a question but do not necessarily test a hypothesis
2. There is no single set and sequence of steps followed in all scientific investigations
3. Inquiry procedures are guided by the question asked
4. All scientists performing the same procedures may not get the same results
5. Inquiry procedures can influence the results
6. Research conclusions must be consistent with the data collected
7. Scientific data are not the same as scientific evidence
8. Explanations are developed from a combination of collected data and what is already known

While an inquiry-based approach is widely endorsed in learning different kinds of subjects at school, however, the effectiveness of the instruction is still debatable. Kirschner, Sweller, and Clark (2006) introduced inquiry learning as a minimally guided or unguided approach and compared its effect with a direct instructional guidance. According to Kirschner et al., the definition of guided instruction is “providing information that fully explains the concepts and procedures that students are required to learn” (p. 75). Then they cited an example of minimal guidance with inquiry learning in science education as “students are placed in inquiry learning contexts and asked to discover the fundamental and well-known principles of science by modeling the investigatory activities of professional researchers” (p. 76). Based on previous literature, they concluded that the guided instruction is superior to minimal guidance since students who are under guided environments get less cognitive load which may be detrimental to learning so that students are likely to learn and remember more after the guided instruction than the minimal guidance approach.

Contrast to Kirschner et al.’s arguments, Hmelo-Silver, Duncan, and Chinn (2007) claimed that inquiry learning, especially in science education, is not without or minimal guidance; rather, by providing expert guidance and proper scaffolding, it re-
duces cognitive load and helps “students acquire disciplinary ways of thinking and acting” (p. 101). In addition, because of various levels of scaffolding in conducting an inquiry, they saw no differences between inquiry learning and guided instruction of Kirschner et al. (2007). Moreover, they emphasized that the purpose of learning is not only for acquiring conceptual knowledge but also for retaining “the flexible thinking skills and the epistemic practices of the domain that prepare students to be lifelong learners and adaptive experts” (Hmelo-Silver et al., 2007, p. 102). Especially in science education, this perspective has been supported by proponents such as Lederman et al. (2014, p. 72) as:

To the overarching goal of developing a scientifically literate populace—the general citizen will need to have a strong knowledge about how scientists construct knowledge and with what level of confidence they should have about that knowledge. They need to know why and how scientists looking at the same data can validly disagree, for example. The scientifically literate citizen will make decisions about controversial topics through their knowledge about scientific inquiry and scientific practices, as opposed to running to their garage to do an experiment

Thus, in this view, Hmelo-Silver et al. (2007) concluded that inquiry learning is often likely to be superior to direct instruction, for instance, in growing scientifically literate citizen.

These argumentations can be understood in a way that inquiry-based science education is accounted in various ways based on the amount of given autonomy to students. As Hmelo-Silver et al. (2007) indicated, inquiry-based learning is introduced with various forms in science education. As shown in Table 1, however, there exist subtle differences in terms and definitions of levels of inquiry from different studies and found no universal criteria. In my studies, therefore, I chose to use the definitions from Zion and his colleagues (Zion, Cohen, & Amir, 2007; Sadeh & Zion, 2012; Zion & Mendelovici, 2012) because of its simplicity and suitability for the context of the studies.

According to Sadeh and Zion (2012) inquiry can be sectionalized into three forms as teacher-directed structured and guided inquiry and student-directed open inquiry. The first level of inquiry is called structured inquiry, which is similar to direct guidance of Kirschner et al. (2006). This level is apt for those who first need to be familiarized with basic inquiry skills such as observing and measuring substances. Thus, it is used for the beginning phase in experiencing scientific inquiry at school (NRC, 2000). However, despite its fundamental role in learning science and effectiveness in acquiring knowledge as Kirschner et al. (2006) argued, since it does not reflect the real nature of science, more and more evidence indicate that the structured inquiry is not sufficient in developing scientific thinking (Zion & Sadeh, 2007), and, thus, it is not often regarded as scientific inquiry in science education (PRIMAS, 2011).

Therefore, in the following section, I exclude explaining about structured inquiry; rather, definitions and effects of guided inquiry and open inquiry are more focused and emphasized.
Table 1. Comparison of levels of inquiry in different studies

<table>
<thead>
<tr>
<th>Zion &amp; al., 2007</th>
<th>Bell et al., 2005 (Lederman, 2009)</th>
<th>Question Method Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>Open</td>
<td>Authentic</td>
</tr>
<tr>
<td>Guided</td>
<td>Guided</td>
<td>P</td>
</tr>
<tr>
<td>Structured (Direct)</td>
<td>Structured</td>
<td>P</td>
</tr>
<tr>
<td>Confirmation (Exploration)</td>
<td>Confirmation</td>
<td>P</td>
</tr>
</tbody>
</table>

Buck et al., 2008 - Problem Background Procedures Results analysis Results communication Conclusions
- NP
- NP
- NP
- NP
- NP

Note. P: provided, NP: not provided

3.1 GUIDED AND OPEN INQUIRY

It is hard to simply define what guided inquiry is since several definitions exist and are used in literature as presented in Table 1. Briefly, Cacciatore (2014, p. 1375) stated that “guided inquiry refers to inquiry in which teachers provide guidance to ensure that students focus their explorations on specific learning objectives, as opposed to open inquiry in which students explore content of their own choosing” and it is “markedly different in instructional approach than the traditional laboratories”. As compared to open inquiry, Sadeh and Zion (2009) describe guided inquiry as it requires students to investigate scientific problems by following teacher guidance. During the process, the teacher should decrease the uncertainty of inquiry process by giving proper questions and procedures; however, the teacher should not provide the answer to the questions nor steps of inquiry. Especially, guided inquiry emphasizes students to involve “in decision-making from the data collection stage, and may come up with unforeseen yet well-conceived conclusions” (p. 384). Consequently, as compared to open inquiry students, guided inquiry students indicated that they spent less time for designing inquiry process, but more time for writing and reporting conclusion (Sadeh & Zion, 2012).

The open inquiry may be the most similar concept of minimal guidance of Kirschner et al. (2006). This form of inquiry is regarded as the most complex level in school inquiry practice and the most similar form of genuine scientific inquiry since it allows students to select a wide variety of questions and approaches (Zion & Mendelovici, 2012). According to Zion et al. (2004), the open inquiry as a dynamic inquiry learning process can be characterized by the four criteria: (1) learning as a process; (2) change occurring during the inquiry; (3) procedural understanding; and (4) affective points of view (see Table 2). However, not like the minimal guidance, it emphasized the ability of the teacher, for instance, in questioning to lead students into the proper stage of the inquiry. Therefore, although it offers the highest autonomy to students, it is not without teacher’s guidance; rather, the proper scaffolds of the teacher are regarded as a key to successful work in the open inquiry (Zion et al. 2007). Despite the critical role of a teacher in open inquiry, however, since teachers may seldom have experienced or been involved in open inquiry investigations, they express difficulties in
implementing this authentic science work at school (Furtak, 2006). Accordingly, an open inquiry-based course for teachers has been focused on in several studies. Zion, Schanin, & Shmueli (2013), for instance, examined 25 science teachers who participated in an inquiry-based academic course for six months in Israel. Based on the open inquiry criteria that Zion et al. (2004) suggested, they characterized and quantified teachers’ open inquiry performances, and found that teachers consistently reported two characteristics of open inquiry—changes occurring during the inquiry and procedural understanding—since the teachers wanted to improve the reliability of the process and results of open inquiry. In addition, from the following up interviews with three participants, teachers indicated self-confidence in conducting an open inquiry, and the open inquiry criteria were continuously implemented in their classroom teaching.

Table 2. The Criteria of Open (Dynamic) Inquiry (Zion et al., 2004)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Categories</th>
</tr>
</thead>
</table>
| Changes occurring during the inquiry | • Changes in the course of the inquiry as a consequence of either field conditions or a literature search  
• An answer to an inquiry question can change the way of thinking  
• Additional ideas emerged and the original inquiry questions were modified  
• Understanding the need to solve technical problems and to suggest practical and creative ideas |
| Learning as a process            | • This stage requires the students to understand the importance of  
• Documentation throughout the inquiry process  
• The connecting thread between inquiry questions throughout the inquiry process  
• Researching additional professional literature throughout the process  
• Devoting adequate time throughout the course of the inquiry |
| Procedural understanding         | • This stage requires the students to understand the importance of  
• Controlling variables  
• The importance of reliable observation and understanding the limitations of isolating variables in the field  
• Understands the importance of maintaining constant conditions  
• Learning how to approach each question from different research perspectives/working methods  
• Controlling, repeating, and maintaining statistics |
| Affective points of view         | • Curiosity, frustrations, surprises, and disappointments occur, especially upon obtaining an unexpected result  
• The student and the teacher initiate activities  
• Persistence and perseverance help ensure the attainment of the experimental results  
• Learning to cope with unexpected results |

Recently, guided and open inquiry practices have been emphasized more and more for school science curriculum across nations. In the U.S.A, for instance, the reformed course description of an AP chemistry requires that the course should be guided inquiry at least six of the laboratory experiments (Cacciatore, 2014). In Israel, high school students majoring in biology must pass a final exam comprising 60% of a theoretical section and 40% of lab work and inquiry project (Sadeh & Zion, 2009). For those practical sections, teachers should choose either guided inquiry or open inquiry and the project lasts for 6-8 months. In Korea, students in grades 3-10 are asked to conduct an open inquiry for at least six hours per year since 2010 (MOE, 2007). Thus, Korean students should conduct an inquiry with a group or individually from planning the investigation to reporting the results.
Despite their various educational values in developing inquiry skills and critical thinking, the effects and relevancy of types or levels of inquiry in teaching and learning science are in debate and controversial among educators. For example, Sadeh and Zion (2009) compared two groups—guided and open—of students in upper secondary school and analyzed their performances in terms of the open inquiry criteria of Zion et al. (2004) (see Table 2). As similar as the results from Zion et al. (2013) open inquiry students used higher levels of changes occurring during the inquiry and procedural understanding than guided inquiry students. Therefore, they concluded that the open inquiry experiences “may shed light on the procedural and epistemological scientific understanding of students conducting inquiries.” Similarly, Berg et al. (2003) argued that open inquiry students indicated more positive learning outcomes and perception of the experiment than other control groups. In contrast, compared to open inquiry, Trautman et al. (2004) reported that guided inquiry reduces students’ frustration from undesirable results or fear of the unknown and prevents a “waste of time” in conducting an inquiry which may exist in the open inquiry (Zion et al., 2007).

3.2 INQUIRY LEARNING EXPERIENCES AND SCIENCE CAREER ASPIRATION IN TERMS OF SOCIAL COGNITIVE CAREER THEORY

As described about student interest in science career in the previous chapter, the career interest is likely to be aroused by students’ previous learning experiences. Especially in science education, students’ inquiry experiences have indicated high correlation with their career expectation (Russell et al., 2007). In addition, the learning experiences are also assumed to give rise to self-efficacy. The correlation between these components can be explained by the Social Cognitive Career Theory (SCCT) by Lent et al. (1994). The SCCT includes a variety of elements related to people’s educational and occupational behavior. This theory is basically founded on the Bandura’s (1986) Social Cognitive Theory (SCT) that highlights the interplay among behavioral, personal, and environmental factors in explaining how learning occurs and why a person engages in a specific behavior. Then, Lent and his colleagues borrowed several concepts from the SCT, connected them to contextual factors and personal inputs, and build models related to occupational behavior. As shown in Figure 2, the SCCT framework especially emphasizes three cognitive-person variables—outcome expectations, personal goals, but mostly, self-efficacy. Indeed, self-efficacy and outcome expectation have been revealed as significant predictors of students’ science performance in much research (e.g., Lavonen & Laaksonen, 2009; Britner & Pajares, 2006) and of career aspiration in science (e.g., Britner & Pajares, 2001). Interestingly, as presented in the model, these core elements are directly affected by learning experiences according to the SCCT framework. However, as Lent (2012) reviewed the previous research that has been done according to the SCCT, performance accomplishment as a learning experience is focused and indicated a strong relation to self-efficacy, but relations between actual learning experiences like conducting an inquiry and other elements have been studied only in a small number of studies on STEM-related career trajectories (e.g., Lent, Lopez, Lopez, & Sheu, 2008; Lent, Lopez, & Bieschke, 1993).

Recently, Wang (2013) examined a nationally representative sample of U.S. from the data of the Education Longitudinal Study of 2002 (ELS: 2002) in order to unearth the factors related to upper secondary school students’ entrance into STEM fields of
study with the lens of the SCCT framework. The results suggest that a STEM major choice is directly affected by the intent to major in STEM, and the intention is directly affected by students’ exposure to science courses as well as self-efficacy and previous academic achievement.

Note. Solid lines indicate direct relations and dashed lines show moderator effects
Figure 2. Social Cognitive Career Theory (Lent et al., 1994)

3.3 IMPLEMENTATION OF INQUIRY-BASED LEARNING

In spite of a variety of positive aspects in conducting an inquiry in science education, however, it is not likely to be practiced as often as expected. Thus, in this section, I shortly describe what factors have been revealed as moderators of teachers’ inquiry implementation.

As is mentioned, inquiry-based learning, especially higher levels of inquiry, requires more time and effort in preparing and conducting experiments than traditional laboratory works, so it sometimes is deemed as a “waste of time” particularly in conducting an open inquiry as discussed. However, not only the issue of time serve but also many other factors have affected teachers’ implementation of inquiry. The following reasons seem to be the most agreed in science education:

- low confidence and competence in teaching inquiry
- lack of time (tight curricula) and resources
- large class sizes
- inadequate professional development
- pressure on standard assessments

(Ramnarain, 2016; Kikis-Papadakis & Chaimala, 2014; Yoon, Joung, & Kim, 2011; Yee-mans, 2011; Harwood, Hansen, & Lotter, 2006; Trautmann et al., 2004; Davis, 2003).

However, the effects of these factors may be different depending on cultural backgrounds of each nation. For instance, Finland is known as no pressure on national standard assessment, decentralized, and teachers’ high autonomy in designing school curriculum (Niemi, 2015). On the other hand, Korea is known as highly centralized
and controlled by the government regarding all the aspects of the educational system (Im, Yoon, & Cha, 2016). Thus, it is assumed that teachers’ inquiry implementation may be affected differently between Finland and Korea because of their different educational environments and systems. Regarding school resources, for another instance, Kikis-Papadakis and Chaimala (2014) reported that there were differences in lacking appropriate laboratory resources in 13 European countries. Despite the plausible differences and following consequences, however, much research only focused on one state-nation, and systematical and statistical comparisons between different cultural backgrounds have not been studied rigorously yet. Thus, it will be beneficial in finding global and regional factors in hindering inquiry practice if different educational systems can be put into a similar statistical model and carefully compared with each other. In Study III, therefore, a comparison study between Finland and Korea had been done. However, since the focus of this dissertation is only the Finnish context, I solely will discuss the result from the Finnish sample thoroughly.
4 SCIENCE EDUCATION AND INQUIRY-BASED LEARNING IN FINLAND

As described in Chapter 1, all my studies have focused mostly on the Finnish sample from the international large scale assessments and inquiry-based science education in the Finnish context. Therefore, in this chapter, I describe the Finnish science education and curriculum in respect of inquiry-based learning.

Finnish education including science has drawn much attention for last decade because of their successful achievements from international comparison studies especially PISA (Programme for International Student Assessment). As Table 3 presents, Finnish students have been placed among top performers since 2000 although it has fallen from its perch. Accordingly, much research has conducted to reveal the secrets and to learn from their educational achievements.

Table 3. Finnish students’ ranking in PISA studies

<table>
<thead>
<tr>
<th>Year</th>
<th>Science</th>
<th>Reading</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2003</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2006</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2012</td>
<td>5</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>2015</td>
<td>5</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>


In general, researchers have presented a general consensus on the factors contributed to Finnish success as “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). Similarly, Finnish students’ success in science is attributed to “a national level core curriculum and implementation process at the municipality level: Science teaching is subject-oriented in the primary and lower secondary levels. Further, teaching aims to transmit the nature of science: Teachers as autonomous and reflective academic experts” (Lavonen & Juuti, 2016, p. 132). Overall, it can be said that Finnish students’ academic achievements may result from the teachers’ professionalism and their collaboration, the educational system increasing students’ equity and equality, and societal belief and support on teacher and school system.

According to the Finnish National Board of Education (FNBE, 2004), in the primary school, students in grades 1-4 had been taught an integrated science subject called “Environmental and Natural Studies”, comprising the fields of biology, geography, physics, chemistry, and health education including the perspective of sustainable development. Thus, the aim of the instruction was that “pupils get to know and understand nature and the built environment, themselves and other people, human diversity, and health and disease” (p. 170). Then, students in grades 5-6 studied two
integrated subjects—Biology & Geography and Physics & Chemistry. In the lower secondary school, grades 7-9 learned five separated science subjects—Biology, Geography, Physics, Chemistry, and Health Education. Since 2016 after a new national core curriculum introduced (FNBE, 2014), students in grades 5-6 also learn science as an integrated subject as Table 4 presents.

Table 4. Comparison of science curriculums between 2004 and 2014 for basic education

<table>
<thead>
<tr>
<th>Grade</th>
<th>2004</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Environmental and Natural Studies</td>
<td>Environmental Studies</td>
</tr>
<tr>
<td>5-6</td>
<td>Biology &amp; Geography and Physics &amp; Chemistry.</td>
<td></td>
</tr>
<tr>
<td>7-9</td>
<td>Biology, Geography, Physics, Chemistry, and Health Education</td>
<td>Biology, Geography, Physics, Chemistry, and Health Education</td>
</tr>
</tbody>
</table>

Regarding an inquiry-based approach, although teachers with high autonomies are not asked to employ specific instruction in teaching science so that they have used a variety of teaching methods (Juuti et al., 2010), the FNBE (2004 & 2014) continuously emphasizes on inquiry-based learning in science education from the first grade. According to the curriculum in 2004 and 2014, students in the first to sixth grades have been asked to formulate questions, plan and carry out research projects, make observations and take measurements, make conclusions, and present the results in science class. In addition, the term inquiry-based learning or inquiry-based approach has been used clearly through the whole national science curriculum repeatedly. For instance, in the curriculum 2004, a “biology instruction must be inquiry-based learning” (p. 176) for grades 5 to 6 and a “biology instruction must be inquiry-based learning, and it is to develop the pupil’s thinking in the natural sciences” (p. 179) for grades 7 to 9. Also, in the curriculum 2014, “the teaching and learning of biology also include working in nature and guiding the pupils...with the help of inquiry-based learning” (FNBE, 2014, p. 408).

In terms of science teaching and learning in the Finnish context, Lavonen and Laaksonen (2009) analyzed the Finnish sample from PISA 2006 and compared it with the average of other OECD countries in order to explain Finnish students’ performance. According to the result of the regression analysis, students’ self-efficacy and self-concept, interest in physics and chemistry, and value on science for the future job indicated as positive predictors to explain students’ PISA performance. With respect to science teaching, teacher’s demonstrations, participation in practical experiments, and drawing conclusion after the investigations were highly correlated with students’ achievement. On the other hand, students’ debate or discussion in school science were seldom happened in Finland and revealed as negative predictors of the performance. Therefore, they concluded that the culture of science inquiry had not been developed yet in Finland, but traditional inquiry practice, such as practical work and teacher demonstration, attributed to Finnish students’ PISA competencies. However, this practical work does not mean a mindless, mere cookbook experiment in the Finnish context. According to Lavonen and Juuti (2016), practical work and demonstration which are deemed as an integral part of teaching and learning of science subjects in Finland are similar to the guided inquiry rather than the structured inquiry based on the criteria of Zion et al. (2007). Indeed, FNBE (2004 & 2014) continuously emphasizes on teacher’ guidance in science inquiry process as well as students’ independent
work. For instance, as Table 5 presents, objectives of physics instruction, specifically in developing research skills, clearly describe what to guide in teaching physics with fifteen statements, and this keynote appears throughout the whole science subjects curriculum guidelines. In addition, while the guidelines for the instruction describes more about practical work and the teacher’s guidance, the assessment criteria for pupil’s learning in physics emphases on, moreover, open inquiry process as “the assessment of experimental work may progress hierarchically from basic working, observation, and measurement skills to instructed research assignments and, finally, to open-ended research” (FNBE, 2014, p. 421). Therefore, in the Finnish context, an inquiry is practiced throughout whole inquiry process from formulating questions to presenting the results by guided or open inquiry practice although the latter form is emphasized more in the recent curriculum.

Table 5. Objectives of instruction in physics in grades 7–9 (FNBE, 2014, p. 419)

<table>
<thead>
<tr>
<th>Objectives of instruction</th>
<th>Significance, values, and attitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1 to encourage and inspire the pupil to study physics</td>
<td></td>
</tr>
<tr>
<td>O2 to guide and encourage the pupil to recognize his or her own competence in physics, set goals for his or her own work, and to work persistently</td>
<td></td>
</tr>
<tr>
<td>O3 to guide the pupil to perceive the significance of competence in physics in his or her daily life, living environment, and the society</td>
<td></td>
</tr>
<tr>
<td>O4 to guide the pupil to use his or her competence in physic in building a sustainable future and to evaluate his or her personal choices in terms of sustainable use of energy resources</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>O5 to encourage the pupil to formulate questions about the studied phenomena and to further develop the questions to serve as a basis for research and other activities</td>
</tr>
<tr>
<td>O6 to guide the pupil to conduct experimental research in cooperation with others and to work safely and consistently</td>
</tr>
<tr>
<td>O7 to guide the pupil to process, interpret, and present the results of his or her own research and to evaluate them and the entire research process</td>
</tr>
<tr>
<td>O8 to guide the pupil to understand the operating principles and significance of technological applications and to inspire the pupil to participate in forming ideas and simple technological solutions and designing, developing, and applying them in cooperation with others</td>
</tr>
<tr>
<td>O9 to guide the pupil to use information and communication technology for acquiring, processing, and presenting information and measurement results and to support the pupil’s learning by using illustrative simulations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge of physics and its use</th>
</tr>
</thead>
<tbody>
<tr>
<td>O10 to guide the pupil to use the concepts of physics accurately and to develop his or her conceptual structures to be increasingly consistent with the concepts of scientific theories</td>
</tr>
<tr>
<td>O11 to guide the pupil to use different meddles in describing and explain phenomena and in making predictions</td>
</tr>
<tr>
<td>O12 to guide the pupil to use and evaluate different sources of information critically and to express and justify different views and a manner characteristic of physics</td>
</tr>
<tr>
<td>O13 to guide the pupil to perceive the quality and development of scientific knowledge and scientific approaches to producing information</td>
</tr>
<tr>
<td>O14 to guide the pupil to obtain sufficient knowledge on interaction, motion, and electricity needed in further studies</td>
</tr>
<tr>
<td>O15 to guide the pupil to apply his or her knowledge and skills in physics in multidisciplinary learning modules and to provide opportunities for getting acquainted with applying physics in different situations, such as in nature, industries, organisations, or scientific communities</td>
</tr>
</tbody>
</table>
In spite of Finnish students’ successful achievements in science, however, they are not without challenges. For instance, Finnish students have reported a lack of interest in science and science-related careers continuously in PISA studies (OECD 2007 & 2016a). Indeed, as I discussed in Chapter 2, Finnish students’ science interest had been indicated as one of the lowest groups in PISA 2006, but the interest was decreased in 2015 more. In addition, their intention in pursuing science careers in future is lower than the average OCED countries. Since students’ non-cognitive factors such as interest affect their literacy skills and career choices significantly, therefore, it is needed to study what and how those factors including learning experiences such as inquiry-based learning are correlated in the Finnish context.
5 AIMS OF THE RESEARCH

As mentioned in Chapter 1, the overall aim of the study is to measure the effect of inquiry-based learning on students’ attitude towards science with the Finnish samples from the large-scale studies. Specifically, the inquiry can be a strong agent in increasing students’ interest in science and science careers, but there is a small number of studies considering students’ socio-cognitive backgrounds to explore mechanisms in explaining how inquiry affect on a construct of interest. In addition, an inquiry is likely to be distinguished by different levels, but the effect of each level on students’ learning outcomes are in debate. Moreover, much research has indicated that teachers have struggled with conducting an inquiry at school because of several obstacles such as time and source limitations, but there is a lack of large-scale evidence in supporting the assertion. Regarding the target sample, it is assumed that inquiry may be widely accepted in teaching school science, but it has not been rigorously studied that what types of inquiry are often practiced and how it works on students’ learning outcomes such as interest or achievement in Finland.

Accordingly, this article-based dissertation aims to tackle following research questions.

1. What types of inquiry have been widely practiced in Finland? (Studies I and II)
2. How do students’ inquiry learning experiences work on students’ interest and achievement, (Study I and II) and students’ aspiration on science careers? (Study II)
3. How do the effects of each level of inquiry differ from each other? (Studies I)
4. What factors affect teachers’ inquiry implementation in Finland? (Study III)
5. How do the factors work differently in the different nation-states? (Study III)

As presented in Table 6, the present dissertation is based on three international large-scale assessments, PISA 2006, TIMSS 2011, and recently published PISA 2015. PISA data derived from student questionnaire are selected in order to construct the measurement of inquiry and other instructional methods and to investigate the effects of inquiry on learning outcomes for Study I and II. For it contains large dataset, samples have been analyzed by advanced statistical tools such as confirmatory factor analysis or structural equation modeling that are widely accepted in analyzing international assessments (Liou & Hung, 2014).

TIMSS data set derived from teacher questionnaire is used in exploring factors related to inquiry implementation. Especially, Korean sample as a proxy of nations of other cultural and educational backgrounds is analyzed comparing with Finnish sample. Therefore, the result can give a hint what are the cross-cultural or regional factors in hindering inquiry practice and how to encourage and support teachers to conduct an inquiry at school. In analyzing the samples, hierarchical multiple regression analysis is conducted. Detailed information about the analytical methods is described in Chapter 6.
Table 6. Overviews of the studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Data and Sample</th>
<th>Aims</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study I</td>
<td>PISA 2006</td>
<td>Constructing measurements representing students’ inquiry practice in the Finnish context</td>
<td>EFA, CFA, SEM</td>
</tr>
<tr>
<td></td>
<td>4714 Finnish students</td>
<td>Measuring effects of inquiry on students’ interest and achievement in science</td>
<td></td>
</tr>
<tr>
<td></td>
<td>51% female, 49% male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study II</td>
<td>PISA 2015</td>
<td>Measuring effects of inquiry on students’ career aspiration with a lens of SCCT</td>
<td>CFA, SEM</td>
</tr>
<tr>
<td></td>
<td>5782 Finnish students</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>49% female, 51% male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study III</td>
<td>TIMSS 2011</td>
<td>Investigating the extent to which factors affect teachers’ inquiry implementation in two different nation-states, Finland and South Korea</td>
<td>HMR</td>
</tr>
<tr>
<td></td>
<td>624 Finnish teachers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>202 Korean teachers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: EFA=exploratory factor analysis, CFA=confirmatory factor analysis, SEM=structural equation modeling, HMR= hierarchical multiple regression
6 METHODS

6.1 SAMPLES: PISA AND TIMSS

As described earlier, the purpose of my research is to examine the samples representing the population of the country. To this end, I used the samples from two most prominent international large-scale assessments (ILSAs), PISA and TIMSS. ILSAs have “two primary types of instruments to help us understand aspects of an educational system: an achievement assessment and background questionnaires” and “the background questionnaires have two primary uses within ILSAs: (1) to help contextualize the assessed educational system: and (2) to optimize population and sub-population achievement estimation” (Rutkowski & Rutkowski, 2017, p. 4).

Samples for Study I and II are from PISA 2006 and 2015 respectively. PISA, or Programme for International Students Assessment, “assesses the extent to which 15-year-old students, near the end of their compulsory education, have acquired key knowledge and skills that are essential for full participation in modern societies” (OECD, 2016a, p. 25). Therefore, the assessment does not solely ascertain students’ reproduction of content knowledge; rather, it focuses also on students’ use of knowledge in unfamiliar or real-life situations and challenges. They accordingly point out the uniqueness of PISA from other international assessments as its “innovative concept of literacy, which refers to students’ capacity to apply knowledge and skills in key subjects, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations” (p. 25). That is, PISA examines students’ competence in the application of knowledge, not in curriculum-based or formal knowledge so that the results can be generalized and compared regardless of different educational systems with various curriculums. Technically, PISA has offered plausible values to represent students’ achievement, since they used several booklets for measuring students’ performance, called an applied matrix sampling, in order to reduce the length of the test. Since they are not interested in individual achievement but more focused on the achievement of the population, they used plausible values that represent the range of the student’s abilities.

In PISA, one subject among reading, mathematics, and science, is focused triennially since 2000. The first assessment examining science literacy was in 2006 and science was again a major domain in 2015 for the second time. As PISA stresses application of knowledge, three competencies in science were measured—“the ability to explain scientific phenomena, to design and evaluate scientific enquiry, and to interpret data and evidence scientifically” (p. 34) as science literacy in 2015 as similar as PISA 2006.

As Rutkowski and Rutkowski (2017) argued one of the primary types of instruments of ILSAs is to gather learners’ background data so as to help contextualize the assessed educational system. In order to ascertain the contextual information, PISA asks students and schools to respond to questionnaires seeking information about

- students and their family backgrounds, including their economic, social and cultural capital.
- aspects of students’ lives, such as their attitudes towards learning, their habits and life in and outside of school, and their family environment.
aspects of schools, such as the quality of the schools’ human and material resources, public and private management and funding, decision-making processes, staffing practices, and the school’s curricular emphasis and extracurricular activities offered.

- context of instruction, including institutional structures and types, class size, classroom and school climate, and science activities in class.

- aspects of learning, including students’ interest, motivation and engagement.

- (OECD, 2016a, p. 29).

This background information is offered with students’ performance data in public simultaneously so that the relationships of these factors with students’ performance can be examined thoroughly through research.

The target population of the PISA studies consists of 15-year-old students studying at the whole educational institutions in each country which means “(i) 15-year-olds enrolled full-time in educational institutions, (ii) 15-year-olds enrolled in educational institutions who attended on only a part-time basis, (iii) students in vocational training types of programmes, or any other related type of educational programmes, and (iv) students attending foreign schools within the country” (OECD, 2009, p. 64). To this end, PISA employs a two-stage stratified sample design. At the first-stage, schools are selected not randomly but based on the PISA stratification framework. In Finnish case, for instance, schools were distinguished by six regions and two areas in 2006 and these stratification variables were adapted differently in each country because of different educational systems (see OECD, 2009, pp. 71-72). Within each specified stratum, the total measure of size and the number of schools are determined in order to include all different types of schools for 15-year-old students in each educational system proportional to the size of schools. This technique is referred as systematic probability proportional to size sampling. After the school selection, at the second-stage, students were randomly selected within the school. As Table 7 presents, 4714 and 5782 Finnish students were selected to represent Finnish population of 15-year-old students in 2006 and 2015 respectively, and most of them were grade 9 in both assessments.

Table 7. Demographic characteristics of the samples of Study I and II

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of students</td>
<td>4714</td>
<td>5782</td>
</tr>
<tr>
<td>Gender</td>
<td>50.6% female, 49.4% male</td>
<td>48.8% female, 51.2% male</td>
</tr>
<tr>
<td>Grades</td>
<td>9th: 89%, 8th:11%</td>
<td>9th: 87%, 8th:13%</td>
</tr>
<tr>
<td>School</td>
<td>155 schools</td>
<td>168 schools</td>
</tr>
</tbody>
</table>

The sample for Study III is selected from TIMSS 2011. Since 1995, TIMSS, or Trend in International Mathematics and Science Study, has reported on student performance in science content domains such as earth science or biology every four years. As well as PISA, TIMSS data covers not only students’ achievement but also students’ attitudes and backgrounds, school resources and climate for teaching, and teacher preparation and instruction (Martin et al., 2012). However, not like PISA samples that I used for Study I and II, since Study III focuses on teachers’ perspective on inquiry implementation, I chose the Finnish teacher sample rather than students. In addition, in order to compare the sample with another cultural background, I selected Korea not only
for I am eligible to explore its cultural and educational backgrounds rigorously from research in the Korean language but also for Korean educational system is highly valued throughout nations because of their successful achievements from several international assessments with exceedingly different educational system to Finland.

As shown in Table 8, samples in Study III comprised of 624 Finnish science teachers from 152 lower secondary schools and 202 Korean science teachers from 150 lower secondary schools. In both countries, there were more female teachers than male, and they have taught science about 15 years. A typical educational difference in science between two countries is that Finnish teachers teach science with separate subjects while Korean teachers teach an integrated science subject in lower secondary school.

Table 8. Demographic characteristics of the samples of Study III

<table>
<thead>
<tr>
<th></th>
<th>Finland</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of teachers</td>
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<td>202</td>
</tr>
<tr>
<td>Gender</td>
<td>61.6% female, 38.4% male</td>
<td>69.1% female, 30.9% male</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>15.91</td>
<td>14.75</td>
</tr>
<tr>
<td>School</td>
<td>152 schools</td>
<td>150 schools</td>
</tr>
</tbody>
</table>

6.2 FACTOR ANALYSIS AND STRUCTURAL EQUATION MODELING: STUDY I AND II

In order to group inquiry-related variables for Study I and II, I used exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA is a statistical technique in reducing variables to a smaller number which tap some common domain when the factorial structure of the measuring instruments is unknown (Wang & Wang, 2012). Thus, “EFA extracts unobserved factors from data without specifying the number of factors or without determining how the measurement items or the observed indicators are loaded onto which specific factors” (p. 29). To become a part of the factor, variables should be strongly correlated with each other, gathered in one factor, and indicated weak relations to other factors during the extraction process. In PISA 2006, students were asked to answer 17 questions regarding teachers’ instructional strategies in teaching science. In order to reduce the number of variables and to group them to represent certain teaching approaches, these questions were first analyzed by EFA. Based on the result from EFA and previous literature, two inquiry-related factors were found and defined as guided inquiry and open inquiry. Then, the aggregations were again analyzed by CFA. CFA is a measurement part of structural equation modeling (SEM). In contrast to EFA, CFA can be used when the theoretical backgrounds or empirical findings for the variables are already known (Wang & Wang, 2012). Thus, “the factors are theoretically defined, and how specific indicators or measurement items are loaded onto which factors is hypothesized before testing the model” so that researchers may “confirm that the factorial structures of the scales in the instrument under study are as hypothesized “(p. 29). Based on the fits of the hypothesized CFA model, factorial validity of the measuring instrument is confirmed (Byrne, 2001). In order to assess the goodness of model fit, traditional cutoff values were applied: RMSEA (Root Mean Square Error of Approximation) below .05 or .08, SRMR (Stand-
ardized Root Mean Square Residual) below .08, CFI (comparative fit index) and TLI (Tucker-Lewis Index) above .95 (Wang & Wang, 2012).

Moreover, in order to check the instrument’ composite reliability, convergent validity, and discriminant validity, Fornell and Larcker (1981) criterion is also adopted in Study I and II. According to Fornell and Larcker (1981), a value of composite reliability .7 or higher indicates sufficient reliability of the model; to ensure convergent validity, the average variance extracted (AVE) value should be .5 or higher; and to assess discriminant validity, the squared root value of AVE for each latent construct should be higher than each latent construct’s highest correlation.

SEM, or path analysis, is used in Study I and II in order to measure direct and indirect effects of inquiry experiences on students’ cognitive and non-cognitive factors. SEM consists of two parts—a measurement part and a structural part—and the former is often called as CFA which is explained in the previous part, and the later one is path analysis. The difference between traditional path analysis and the structural part of SEM is that “the structural model defines the relationships among the latent variables, and it is estimated simultaneously with the measurement models”; accordingly, “if the variables in a structural model were all observed variables…the model reduces to the traditional path analysis in sociology or simultaneous equation model in econometrics” (Wang & Wang, 2012, p. 6). In Study I and II, each inquiry-related factor consisting of several variables is constructed by EFA and CFA, and is used as latent variables rather than observed variables as shown in Figure 3 and 4. As Kline (2011) describes “latent variables in SEM generally correspond to hypothetical constructs of factors, which are explanatory variables presumed to reflect a continuum that is not directly observable” (p. 9). However, although the hypothesized models seem like presenting causal relations between variables, the results of the analyses “cannot generally be taken as evidence for causation” and in non-experimental designs “no statistical technique…can somehow prove causality” including SEM (p. 8).

6.3 HIERARCHICAL MULTIPLE REGRESSION: STUDY III

Hierarchical multiple regression (HMR) is used in Study III in analyzing factors affecting teachers’ inquiry implementation sampled from TIMSS 2011. Since large-scale samples often indicate a nested data structure, I initially considered to analyze the data with multilevel modeling (MLM) which calculate the within-effects of the sample. For instance, as well as students, teachers may be nested within the schools in TIMSS 2011 data so that they may indicate similarities in their behavioral characteristics such as conducting an inquiry. In order to confirm the nested structure in using inquiry practice within or between schools, the intra-class correlation coefficient (ICC) can be examined. The ICC value reflects the amount of between-school variability relative to total variability (the sum of between and within school variability); a large ICC value indicates large differences between schools but small differences within schools in using inquiry; oppositely, a small ICC value indicates small differences between school but large differences within schools in implementing inquiry in science; thus, the small value of ICC (generally less than 5 % (Bliese, 2000)) means that the data has an insignificant clustered structure. Against the expectation, however, the ICC values of the samples of Finnish and Korean teachers indicated lower than 5%; that is, almost no difference of teachers’ inquiry implementation between schools is found in both Finland and Korea; accordingly, instead of MLM, I used HMR in Study III.
HMR is a framework for model comparison of several regression models by cumulating predictors at each step. In Study III, I first divided factors into two levels—teacher level and school level. Then, teacher level factors are entered step by step from demographic information such as teaching experiences or gender as control variables in Model 1 to teachers’ attitudes such as confidence in teaching science or collaboration to improve teaching as independent variables in Model 3. At last, school level factors such as school resources for science education is entered in the final model, Model 4 (see Table 11 and 12). Through the cumulating process, I checked the improvement of $R^2$ value which presents the proportion of explained variance in the dependent variable and the changes of statistical significance of variables on regression models in order to identify the important and common predictors in implementing inquiry practice at the school in both Finland and Korea.
7 RESULTS OF THE ORIGINAL STUDIES

7.1 STUDY I


Two main aims of this study are to find variables representing different types of inquiry practice in Finland from PISA 2006 data and to measure the effects of inquiry on students’ interest and achievement. For the former purpose, EFA is conducted with seventeen teaching strategies, and then CFA is conducted with assessing the fit of the different kinds of competing models. The result indicates that four student-centered approaches (SCAs) are grouped by the factor analyses, and two are related to guided inquiry and open inquiry in the Finnish context. The measurement model also indicates satisfactory reliability and validity regarding Fornell and Larcker (1981) criterion. Thus, with these four latent variables representing student-centered approaches, SEM is conducted to measure correlations of these variables with interest and achievement. In addition, six students’ background information were simultaneously included in the model as control variables—socio-economic status, career aspiration, instrumental motivation, enjoyment, immigration status, and self-study hours—based on Walberg’s (1981) theory of educational productivity.

As shown in Figure 3, four latent variables representing SCAs were used as independent variables, and students’ interest and achievement were placed in dependent variables. Standardized path coefficients are shown in the figure, with solid lines to identify significant and dashed lines for non-significant coefficients. In addition, in Table 9, standardized coefficients of all variables including control variables are presented.

With respect to interest, guided inquiry experience was positively related to students’ interest in science while open inquiry indicated a non-significant relation with interest. The correlation of guided inquiry with interest (β = .07, p < .05) is as similar as the effect of gender on it (β = .07, p < .001) and higher than socio-economic status (β = .03, p < .05).

Regarding the relationship between inquiry and achievement, guided inquiry indicates continuously positive correlation with students’ science literacy whereas open inquiry presents strong negative relation to it. The effect of guided inquiry (β = .39, p < .001) on achievement is approximately four times higher than the effects of students’ gender (β = .09, p < .001), instrumental motivation (β = .10, p < .001), career aspiration (β = .10, p < .001), enjoyment in science (β = .10, p < .001), and even socio-economic status (β = .20, p < .001). On the other hand, the negative effect of open inquiry (β = -.59, p < .001) is approximately 6 times higher than those background predictors. Comparing with the total effects of other student-centered approaches like relevant topics (β = .13, p < .01) and discussion (β = -.09, p < .001) on achievement, guided inquiry is superior (β = .40, p < .001) and open inquiry is inferior (β = -.59, p < .001).

*Model fit: Chi-square = 3680.589 (.000), df = 300, CFI = .943, TLI = .934, SRMR = .073, RMSEA = .050

Figure 3. SCAs Path Analysis
Table 9. Standardized regression weights on achievement and interest

<table>
<thead>
<tr>
<th>Achievement</th>
<th>Estimate (β)</th>
<th>S.E.</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant Topics</td>
<td>.12</td>
<td>.04</td>
<td>**</td>
</tr>
<tr>
<td>Open Inquiry</td>
<td>-.59</td>
<td>.03</td>
<td>***</td>
</tr>
<tr>
<td>Guided Inquiry</td>
<td>.39</td>
<td>.03</td>
<td>***</td>
</tr>
<tr>
<td>Discussion</td>
<td>-.09</td>
<td>.03</td>
<td>***</td>
</tr>
<tr>
<td>INSTSCIE</td>
<td>.16</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>GEN</td>
<td>.09</td>
<td>.01</td>
<td>***</td>
</tr>
<tr>
<td>INSTSCIE</td>
<td>.10</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>JOYSCIE</td>
<td>.10</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>SCIEFUT</td>
<td>.10</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>ESCS</td>
<td>20</td>
<td>.01</td>
<td>***</td>
</tr>
<tr>
<td>IM1</td>
<td>-.11</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>IM2</td>
<td>-.02</td>
<td>.01</td>
<td>.184</td>
</tr>
<tr>
<td>SS</td>
<td>-.03</td>
<td>.01</td>
<td>.069</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interest</th>
<th>Estimate (β)</th>
<th>S.E.</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant Topics</td>
<td>.09</td>
<td>.03</td>
<td>**</td>
</tr>
<tr>
<td>Open Inquiry</td>
<td>.004</td>
<td>.03</td>
<td>.869</td>
</tr>
<tr>
<td>Guided Inquiry</td>
<td>.07</td>
<td>.03</td>
<td>*</td>
</tr>
<tr>
<td>Discussion</td>
<td>-.02</td>
<td>.02</td>
<td>.371</td>
</tr>
<tr>
<td>GEN</td>
<td>.07</td>
<td>.01</td>
<td>***</td>
</tr>
<tr>
<td>INSTSCIE</td>
<td>.12</td>
<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>JOYSCIE</td>
<td>.44</td>
<td>.02</td>
<td>***</td>
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<tr>
<td>SCIEFUT</td>
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<td>.02</td>
<td>***</td>
</tr>
<tr>
<td>ESCS</td>
<td>.03</td>
<td>.01</td>
<td>*</td>
</tr>
<tr>
<td>IM1</td>
<td>.03</td>
<td>.01</td>
<td>**</td>
</tr>
<tr>
<td>IM2</td>
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<td>.287</td>
</tr>
<tr>
<td>SS</td>
<td>.03</td>
<td>.01</td>
<td>*</td>
</tr>
</tbody>
</table>

*** > .001, ** > .01, * > .05

7.2 STUDY II


In this study, how young learners’ inquiry experience can affect their career choice is investigated including learners’ socio-cognitive background based on SCCT. To that end, PISA 2015 data is used and is analyzed by SEM. Initially, I intended to use similar variables related to guided inquiry and open inquiry as I used in Study I in order to examine the effects of different levels of inquiry on the dependent variable. However, because of a biased response regarding open inquiry (students answered they almost never experienced open inquiry) and a disagreement with reviewers in using variables related to guided inquiry, I excluded those terms—guided and open
inquiry—but defined inquiry in accordance with the Finnish context in this study. Nevertheless, I distinguished variables between guided inquiry and open inquiry in describing descriptive statistics.

In the descriptive statistics, I compared Finland with average OECD countries by presenting Cohen’s d value which measures different effect sizes between two groups. The result indicates that there is very small or no differences in conducting guided inquiry between samples of Finland and all OECD. However, regarding four variables related to open inquiry, the result indicates that Finnish students clearly less experienced open inquiry than the average of OECD countries. In addition, the patterns in frequency of five variables related to inquiry practices (which is close to guided inquiry) are revealed as similar between Finland and OECD. Interestingly, however, of students from both Finland and overall OECD countries, about 30% had no chance in conducting a practical experiment at school.

As another descriptive statistics, four core constructs of this study—interest in learning science, outcome expectation, self-efficacy, and inquiry-based learning—are compared between Finland and OECD. An interesting finding of the result is that while Finnish students marked lower in inquiry experience, interest in science, outcome expectation and self-efficacy, correlations between inquiry and other attitude variables are higher in Finnish sample than other OECD countries. That is, although Finnish students experienced less inquiry, the effect of the instruction on students’ non-cognitive factors is more positive than the average OECD countries.

With the four core constructs, CFA is conducted, and the result indicated that the measurement model reached the proper level of model fit. In addition, as similar to Study I, reliability and validity of the measurement model is investigated based on Fornell & Larcker’s (1981) criterion and the result indicated that composite reliability, convergent validity, and discriminant validity are satisfactory.

Finally, as shown in Figure 4, the hypothesized SCCT model is examined including fit of the model (CFI=.91, TLI=.89, RMSEA=.038 (90% C.I.=.036, .039)). Unstandardized path coefficients are demonstrated in Figure 4 and the numbers in parentheses refer to standardized coefficients (all paths p < .01). Regarding direct correlations of inquiry-based learning experiences (IBL) on other variables, it indicated positive relations with self-efficacy (SE, .44, p < .01) and outcome expectation (OE, .41, p < .01) in science while it presented negative correlation with science-related career trajectory (FUT, -.18, p < .01). However, all indirect paths between IBL and FUT through other constructs indicated positive correlations (sum of indirect correlation= .41, p < .001), and, thus, their overall correlation became positive (.23, p < .001). This final positive relationship between IBL and FUT was mainly attributed to the mediation effect of students’ outcome expectation (OE) between IBL and FUT, since OE has strong positive correlations with both IBL (.41, p < .01) and FUT (.57, p < .01). Hence, the large portion of the indirect effect of inquiry learning experiences worked through OE (.23, p < .001).

Regarding future career orientation (FUT), all three latent variables—SE, OE, and ILS (interest in learning science)—showed positive relations to FUT (.14, .57, .13 respectively with all p values under .01) while OE indicated as the most powerful predictor of students’ career trajectories directly (.57, p < .01) and totally (sum of direct and indirect correlation=.61, p < .001). Therefore, as OE mediates the power of IBL, it also largely mediates the power of SE on FUT, so that the unstandardized coefficient of SE on FUT increased more than twice (.37, p < .001).
In addition to the core constructs, as SCCT includes learners’ personal background in the model, I put gender, socio-economic status, and immigration status as control variables in the hypothesized model of this study. According to the results, gender differences were found in all latent variables (p < .001) except interest in learning science (p > .05). While boys indicated higher self-efficacy than girls, girls indicated higher outcome expectation and career aspiration than boys. Students’ socioeconomic status affected on science self-efficacy, interest, outcome expectations, and future career orientation. Regarding immigration status, students of the first generation of immigrant indicated lower self-efficacy but higher interest in science and the second generation indicated higher outcome expectation in learning science than native. However, these data must be interpreted with caution because, in Finnish sample, the number of students with an immigrant background was very small (4%).
This study aims to investigate the extent to which various teacher- and school-level factors have respectively affected teachers’ implementation of inquiry-based learning at lower secondary schools as a comparison study of Finland and South Korea. To this end, several predictors are included in the statistical model—emphasis on science investigation, teaching experience, gender, educational level, major in education and science, class size, emphasis on exam, professional development for IBL, confidence in teaching science, collaboration to improve teaching, and school resources for science education.

According to the result of descriptive statistics, significant differences were found in class size, exam emphasis, and professional development (PD) for IBL between two countries. Class sizes were twice larger in the Korean science classes (34.05) than the Finnish ones (15.5), and Korean teachers focused largely on the exam (.74) than Finnish teachers (.28). While Korean teachers participated much more in PD for IBL (.46) than Finnish (.08), their confidence in teaching science was lower (8.49) than Finnish (9.10). Collaboration in teaching science and school resources were higher in Korean schools (9.67, 11.64) than Finnish schools (9.37, 10.65) although the effect sizes were moderate or small.

Results of HMR indicates that Finnish teachers’ backgrounds, such as their teaching experience, gender, educational level, and major in science have a non-significant association with IBL implementation, thus these factors did not affect the frequency of inquiry practice in Finnish secondary schools (see Table 11). On the other hands, as shown in Table 12, Korean teachers’ education level is negatively related to IBL implementation.

As for the effect of class size, while it negatively contributed to Finnish teachers’ inquiry implementation, it was non-significant in the case of Korean teachers. Regarding PD in the Finnish case, PD indicated a statistically significant correlation with the implementation before controlling teachers’ confidence and collaboration variables. That is, a certain level of inquiry can be expected from Finnish teachers as a consequence of the PD. However, the effect of PD for IBL was reduced and become insignificant when factors for teachers’ confidence and collaboration in teaching science were taken into account. It means that substantial part of the effect of PD for IBL was mediated by teachers’ confidence and collaboration. Hence, it can be assumed that the Finnish PD program was so successfully conducted in promoting teachers’ confidence and collaboration for 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 Korean models, but statistically, it was so non-significant that it cannot be concluded as the PD program successfully influenced on teachers’ confidence or collaboration in teaching science as well as implementing inquiry in Korea.

In both countries, confidence in teaching science was the most positive indicators toward implementing IBL in school science, and the effect persists after controlling for all teacher factors and school factor in the final model. In addition, collaboration for improving science teaching also indicated the strong positive effect on IBL implementation in Model 3 and 4 in both countries.
Regarding school resources for science education, it was positively correlated to IBL practice in Finland, whereas it was statistically non-significant in Korea. This means that when there were more resources, there were more inquiry practices in Finland, but Korean teachers conducted inquiry regardless of school resources.

Table 11. Effects of factors on teachers’ IBL implementation in Finland

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>-.021</td>
<td>-.04</td>
<td>-.03</td>
</tr>
<tr>
<td>Gender</td>
<td>.00</td>
<td>.01</td>
<td>-.03</td>
<td>-.03</td>
</tr>
<tr>
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<td>.00</td>
<td>.00</td>
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<td>-.07</td>
<td>-.06</td>
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<td>.06</td>
<td>.07</td>
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<td>.06</td>
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<tr>
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<td>***.26</td>
<td>***.23</td>
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<tr>
<td>Collaboration to Improve Teaching</td>
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<td></td>
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<td></td>
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</table>

Table 12. Effects of factors on teachers’ IBL implementation in Korea

<table>
<thead>
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<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
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<td>***12.78</td>
<td>***9.11</td>
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<td>1.655</td>
<td>***4.235</td>
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8 DISCUSSION OF THE RESULTS

The overarching objective of my research is to investigate the way to increase students’ interest in science and science careers by means of inquiry-based learning and to investigate factors impeding teachers’ inquiry practice in order to support conducting an inquiry at school in Finland. To that end, samples representing Finnish population from international large-scale assessments, PISA and TIMSS, are used and analyzed with several statistical techniques such as structural equation modeling. In this chapter, main findings, implications and limitations from Study I, II, and III will be discussed in terms of guided inquiry, open inquiry, and inquiry environment in order.

8.1 BRIEF SUMMARY OF STUDY I, II, AND III

In Study I, based on the results from EFA and CFA, variables from 17 questions regarding teaching methods used in science class were grouped as factors indicating two inquiry-based approaches, guided and open inquiry. According to the findings from Study I and II, it is revealed that in Finland guided inquiry was dominantly practiced at school science and it indicated a strong positive effect on students’ performance, and its positive effect on interest was also statistically significant. On the other hand, open inquiry-based learning was almost never conducted at school, and it indicated a strong negative effect on students’ performance and statistically non-significant relation to their interest. The contrast result of guided inquiry and open inquiry may be attributed to the effectiveness of different levels of inquiry on students’ learning outcomes. Since open inquiry is the most complex level of inquiry and students often indicate a lack of procedural knowledge of what and how to investigate in scientific experiments at school, as Arnold et al. (2014) argued students often need proper scaffolding in designing investments such as hypothesizing of dependent, independent, and confounding variables. Thus, without teachers’ adequate intervention on each inquiry phase, students are not likely to be successful in open inquiry practice. In addition to the levels of inquiry, the result can be attributed to the quality of inquiry practice. As mentioned earlier, Finnish students often experienced guided-inquiry as is dominant in Finnish science class culturally. On the other hand, as Lavonen and Laaksonen (2009) and Study II presented based on PISA 2006 and 2015 respectively, Finnish students have been almost never allowed to conduct open-ended inquiry; thus, insufficient experience in open inquiry, for both students and teachers, has probably resulted in poor quality of open inquiry implementation and intervention. Accordingly, the open inquiry was probably indicated as a negative effect on students’ achievement.

Regarding the results from Study II, future career aspiration in science can be promoted by inquiry learning experience, or guided inquiry practice, in school science for 15-year-olds students. More specifically, students clearly were more interested in science career when more guided inquiry activities, such as conducting a practical experiment or drawing a conclusion after the investigations under the teacher’s instruction, were offered at the school. This result is in line with previous studies that students who are more exposed to science learning intend to continue more in science majors (Wang, 2013; Russell et al., 2007). Considering the direct negative correlation
in the model between inquiry and future career, the significant relationship between them resulted from the high positive correlation of inquiry with students’ self-efficacy and outcome expectations. That is, inquiry experiences indirectly increase students’ interest in science career by increasing students’ self-efficacy and outcome expectations. In general, on the occasion of job entrance, as people consider their ability and interest (e.g., Eccles, 2005), so do students consider their ability based on self-efficacy belief (Marsh & Yeung, 1997; Parker et al., 2013), especially in science (Wild, 2015; Taskinen et al., 2013; Simon & Osborne, 2010). Hence, the result can be interpreted that in the case of students who often get chances to involve in guided inquiry learning, they will have more belief in one’s ability and interest in science so that their intent to study or work in science area will be increased. However, this result from Study II is not related to another level of inquiry, open inquiry, since we excluded variables related to the open inquiry in the model. As was revealed in PISA 2006 (Lavonen & Laaksonen, 2009), Study II also indicated that Finnish students seldom experienced open inquiry practice at school science.

Inasmuch as boys show more interest in science and science-related career in general, it was an interesting finding that girls presented higher outcome expectation and career aspiration in Finland. Given the significant effect of outcome expectation on career orientation in Study II, female students’ higher science-related career aspiration can be attributed to their higher outcome expectation than boys. This result can be explained by unique traits of the Finnish context. According to PISA 2015 (OECD, 2016a), Finland is the only country in which girls are more likely to be top performers than boys while other 33 participating countries indicated the large share of top performers among boys than among girls.

The result of Study II also presented that although Finnish students indicated a lower level of inquiry experience, the correlation between inquiry and other constructs are higher than that of the average of OECD countries. That is, Finnish students are likely to experience better inquiry practice in science lessons so that more inquiry practice may result in higher self-efficacy and outcome expectation; it may lead Finnish students’ higher achievement in PISA.

Study III examined factors related to inquiry implementation, and the study found several factors triggering or hindering teachers’ inquiry practice. Firstly, it indicated that the inquiry implementation in lower secondary schools could 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; Windschitl, 2000), it requires teachers’ determination to explore a new way of teaching and belief in their capabilities to conduct it successfully. Therefore, the result can be interpreted as when teachers had more confidence in their abilities in teaching science including inquiry skills, it happened more frequently in school science. This result is in line with previous studies that teachers’ school practices depend mostly on their belief and confidence (Davis, 2003; Loucks-Horsley, et al., 2003). In addition to teachers’ confidence, their collaboration for improving teaching science also indicated as a strong predictor to promote IBL implementation in Finland. The result is consistent with previous research (Bolte et al., 2014; Snow-Gerono, 2004) that when teachers had more chances to collaborate each other, they tried more inquiry-based teaching in the class. 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 network can give them chances to plan and prepare instructions together so as to get the materials more sufficiently than
individual preparation, and to encourage each other to try out new ideas. Moreover, they could learn from each other by reflecting and sharing what they have learned from the experiences. Interestingly, the findings showed that the positive effect of confidence and collaboration towards IBL implementation was partially derived from the professional development (PD) of IBL in the statistical models. Therefore, the result can be interpreted as inquiry-related PD programs in Finland was likely to increase teachers’ confidence and collaboration, and, thus, teachers who participated in the programs implemented more inquiry than those who did not involve in the programs. Smith (2013) similarly found that in successful collaborative professional development programs, teachers’ confidence and competence in teaching science substantially were increased as well as pupils’ attitude towards learning science. However, despite the positive effect of the program on teachers’ inquiry practice, the proportion of Finnish teachers participated in the training program was much lower than the Korean teachers. The result is in line with the TALIS 2013 report (Teaching and Learning International Survey) by OECD (2014) that the chances to access to and the rate of Finnish teachers participating in formal induction programs were lower than other participating countries in the survey. Considering the positive correlation between the PD and inquiry practice in Finland from Study III, a way to increase opportunities and participation in the training programs should be thoroughly studied in the Finnish context.

8.2 IMPLICATIONS

Theoretical Implications

The results from Study I and II support and oppose some of the theoretical perspectives adopted from other studies regarding the levels of inquiry. On the one hand, the different effects of two inquiry activities on students’ achievement are in line with the findings from Minner et al.’s (2010) meta-analysis and Jiang and McComas’ (2015) PISA study. Both studies indicated that when students are involved in conducting and concluding the investigation, rather than in designing or asking their own questions, they presented clearly better academic achievement. Thus, the result of this dissertation also supports that, since not all levels of inquiry are effective on increasing students’ knowledge acquirements, thus, teachers should consider different inquiry strategies based on their purpose of instructions. On the other hand, with regard to relationships between students’ attitude and inquiry, the result was inconsistent with Jiang and McComas’s (2015) PISA 2006 study, which reported more openness of inquiry increased students’ interest in science, including Finnish sample. Given that both studies used similar variables in dividing and analyzing guided and open inquiry, the result is controversial. However, among various interest-related constructs in PISA 2006, since they used a different interest item, named embedded interest scales (Olsen & Lie, 2011), the result can differ from each other. The embedded item was an innovative approach to measuring students’ interest in very specific contexts. Nevertheless, unlike a general expectation, since it has continuously indicated an insignificant relationship with students’ performance, using this item as a representative indicator of students’ interest is inconclusive yet (Bybee & McCrae, 2011; Drechsel, Carstensen, & Prenzel, 2011; Olsen & Lie, 2011).
Regarding implementation of inquiry, despite significant differences of teachers’ emphasis on exam between Finland and Korea, it did not influence on IBL implementation of both countries. Specifically, Korean teachers’ emphasis on assessment was almost three times higher than Finnish teachers’, but the frequency of conducting investigation indicated similarly in both countries. On the one hand, the result is in line with Ripley’s (2014) report that Korean educational system is more based on competition than Finnish system. On the other hand, the result conflicts with the previous research which argued that the assessment pressure is likely to prevent the time-consuming experimental work in school science so that teachers are more likely to transfer the knowledge for preparing the assessments (Trautmann et al., 2004; Yeomans, 2011). In spite of non-relationship between the pressure on evaluation and frequency of teachers’ IBL practice, however, since we didn’t examine effects of the pressure on the quality of teachers’ IBL practice, it needs further research to investigate the influence of teachers’ perception of preparing exam on quality of IBL practice in Finland and Korea.

This dissertation also contributes to the literature on modeling and grouping inquiry-related variables in analyzing large-scale data. In terms of inquiry-related variables in PISA studies, Study I revealed what variables represent guided inquiry and open inquiry based on PISA 2006, and this result was reconfirmed in Study II with PISA 2015 data. Indeed, variables related to the inquiry have been differently grouped in PISA studies so that the effects of inquiry-related factors were inconsistent with this dissertation. For instance, in PISA 2015, PISA grouped all inquiry variables together including both guided and open inquiry, and it indicated that inquiry-based instruction was negatively related to science performance, and statistically non-significant with science career aspiration in case of Finland (see OECD, 2016b, p. 72). Moreover, in PISA 2006, model fit for CFA with science teaching and learning including inquiry variables was insufficient in Finnish sample (RMSEA=.094, CFI=.83) as well as most of other countries (see OECD, 2009, p. 334). Therefore, variables related to the inquiry should be reconsidered and recalibrated in conducting large-scale studies so that the proper result related to inquiry could be informed.

In terms of developing the Inquiry-SCCT questionnaire for measuring the effects of inquiry learning experiences within the socio-cognitive mechanisms, Study II indicated that the given survey questionnaire was well suitable for the hypothesized model showing overall good model fits which closely realized SCCT model with science inquiry experiences. In addition, as discusses, the direct effect of inquiry on career aspiration was negative although the overall effect was strongly positive. That is, if a simple linear regression were conducted between inquiry and career aspiration, the result would be inconsistent with this dissertation. Thus, I argue that when examining psychometrics, proper modeling should be taken into consideration as I have done through Study II. Although it must be validated with other populations of students, I expect that this model will be beneficial to researchers, evaluators, and educators in measuring the effect of inquiry-based learning programs on students’ attitudes and career choices.

Practical implications

In practical points of view, this dissertation offers several implications. According to students’ response in Study II, more than 30% of 15-year-olds students did not get a chance to involve in practical experiments in the laboratory in Finland, and the proportion is much higher than nine years ago from the result of PISA 2006 (20%).
Although the Finnish educational system allows high autonomy to the teacher in managing class in general (OECD, 2007), their autonomy also is affected by various environmental factors. For instance, according to Study III, Finnish teachers’ inquiry implementation were highly correlated with teachers’ confidence in teaching science and their collaboration to improve science teaching. In addition, inquiry-related professional development, class size, and school resources were also significantly related to Finnish teachers’ inquiry practice. Specifically, the result from Study III shows that Finnish teachers indicated lower confidence in teaching science than average OECD countries, and, thus, it is likely to cause the low frequency of inquiry practice in Finland. Hence, the results demand that a teacher educator has to focus more on how to improve pre- and in-service teachers’ confidence and collaboration in conducting an inquiry at school through their teaching program in order to be widespread inquiry teaching possible. Moreover, the class size and school resources were indicated as barriers in implementing IBL in Finland. Therefore, Finnish policy makers and educators have to consider how to manage the class sizes and school resources if they want to emphasize more on scientific inquiry at school. Without controlling a proper number of students in one class and school resources in one school, the inquiry will be less practiced in Finland. In sum, it needs a comprehensive approach in order to increase Finnish teachers’ inquiry practice so as to increase students’ interest.

Regarding open inquiry, according to Study I and II, it is revealed that the open inquiry culture has not been developed yet in Finland. Nevertheless, since the new curriculum emphasized the role of open inquiry (FNBE, 2014) and it shows a positive relationship with students’ cognitive and non-cognitive factors (Sadeh & Zion, 2012; Berg et al., 2003), the teacher should take open inquiry into account in teaching science. Considering that Finnish teachers have successfully implemented the national level core curriculum so far, I assume that the open inquiry practice will be increased as time goes by in Finland. However, in the sense that it is the most complex level of inquiry (Zion & Mendelovici, 2012), and that teachers have difficulty in adopting this approach without ample experiences of scientific research (Roth et al., 1997), it must be dealt with professional developments for pre- and in-service teachers. As Lunsford et al. (2006) reported, by providing pre-service teachers with the basic level to the complex level of inquiry, teachers can progressively develop scientific and critical thinking as well as the production skills of complex inscriptions as similar as what scientists actually do.

8.3 LIMITATION AND SUGGESTION FOR FURTHER RESEARCH

Since the aim of this dissertation was to analyze secondary data, there are some limitations to the survey design. First, the PISA data related to teaching methods only considered the frequency, not the quality or preference of the methods. Therefore, the result can solely be interpreted in the aspect of how the frequency of the methods affects students’ attitude and performance. Regarding examining the quality of inquiry instruction, however, Study II offers a hint to researchers in investigating the quality with ILSAs. Although students’ achievements are not the primary aim of Study II, the better achievement of Finnish students was probably derived from their increasing self-efficacy and interest in science by their learning experiences as our model demonstrated since these two constructs are highly related to achieve-
ments as well. In other words, the result shows that the correlation between inquiry and other constructs are higher than that of the average of OECD countries. That is, Finnish students are likely to experience better inquiry practice in science lessons so that more inquiry practice may result in higher self-efficacy and outcome expectation; it may lead Finnish students’ higher achievement in PISA. With this assumption (or premise), the model can be developed, improved, and analyzed by adding several variables related to qualities of inquiry practice based on previous literature. Second, the data was collected only from students’ perspective of the teaching methods, not from the teachers’ perspective. Since the Likert-scale measurement was used in PISA 2006, the interval between points probably did not present equal changes in attitude for all peers, and they answered according to what they felt at the time. Hence, to produce a more precise result, the teachers’ perspective must be included in the survey to compensate for students’ responses.

A limitation of study design of Study II is that it is limited by cross-sectional designs, so it would not provide more information about the stability of students’ longitudinal decision in pursuing their career aspiration. Therefore, I suggest conducting a follow-up survey with the PISA 2015 participants in Finland so that it can be revealed how they actually choose their academic and career entrance currently in the near future and that we could extend our knowledge about the effect of inquiry in terms of SCCT.

Regarding sampling, since TIMSS 2011 was planned and concerned more about participated students than teachers, while the TIMSS 2011 student samples represent their population of countries, the samples of teachers using in Study III does not represent their population exactly. In addition, because the only small number of teachers from each school were involved, usually two or three teachers from each school, its cluster effect did not appear in the study. Therefore, for further research, I suggest designing the survey, for instance, by using stratified and cluster sampling for teachers, as TIMSS has done for students, so that the teacher samples can represent the population and show a cluster effect.

Lastly, since the main aim of all studies were to examine the Finnish sample solely, it cannot be generalized to all other countries. Since every country has its own culture, educational system, value, and tradition, the attitudes of students in different countries could be various, and it could be hard to reach the same conclusion. For further research, therefore, more data from different countries can be analyzed to include consideration of their various backgrounds. However, the model needs to be designed more cautiously considering different variables which effects in various ways depending on cultural, economic, and developmental backgrounds. Nevertheless, by providing a comparison with OECD or a specific country, South Korea, and reporting Finnish results from old and newly published PISA study, this dissertation contributes to educators and researchers on extending the analysis to other educational systems.

### 8.4 CONCLUSION

Behind Finnish students’ success story in science achievement, there is another phenomenon that students are not interested in science. This is not only true for Finland, but also for other high-score achievers such as Korea, the Netherlands, or Australia (OECD, 2007). According to the results from this dissertation, Finnish students get more interested in science and science professions by experiencing more guided-in-
quary learning. In addition, this increased interest in science results in better achievement. Therefore, I encourage science teachers to use guided inquiry more frequently in order to increase both students’ interest and achievement in school science. However, the results of this study do not advocate the frequent practice of open inquiry with lower-secondary school students in science. I assume that this result is probably due to the low frequency of using this student-centered pedagogy in Finland. However, as mentioned earlier, since open inquiry is the most complex level of inquiries; it needs proper intervention by teachers, but, it is not yet culturally developed in Finland; thus, it needs adequate professional development for pre- and in-service teachers for successful implementation. However, as the limitation indicates, the result of the study is only about the frequency of learning experiences with inquiry practice, not about quality. Thus, I again suggest research to conduct more in-depth studies about, especially, the culture of open inquiry practice in Finnish schools and students’ perceptions of open inquiry. Regarding other countries with different cultural backgrounds of science pedagogies, I recommend to conduct analysis with the same model using PISA data, but, based on the own result of factor analyses and reviewed literature related to their own contexts. I assume that factors related to each level of inquiry might be aggregated differently depending on students’ response to the questionnaire and teachers’ actual practice at school because of disparate educational cultures. Thus, researchers should first consider the context of each educational environment before conducting statistical analyses in order to measure and find more accurate results.

Regarding inquiry implementation, 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 Finland and Korea. In general, teachers’ confidence in teaching science has been emphasized, because of its positive effect on students’ achievement and motivation (Martin et al., 2012). In addition to the effect, I add one more evidence that why teacher educators should consider teachers’ confidence more in their teacher training programs which aim to increase inquiry practice. However, each population has done different practice, possesses diverse cultural backgrounds, and, thus, might indicate different needs in teacher training as Finland and Korea are different. Therefore, I encourage to analyze each sample from TIMSS with other cultural backgrounds respectively followed by the progression I suggested. In addition to their confidence, teachers’ communities for collaboration in developing teaching practice can play an import role in increasing inquiry-based science education, because of its demanding nature of creating teaching materials and curriculum, and of reflecting own practice. Thus, in order to encourage teachers’ consistent inquiry practice, it is required to build a sustainable environment for teachers in cooperating and collaborating in and out of school.
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STUDY I

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This dissertation investigates the effect of inquiry-based science education on Finnish students' attitude and performance based on international large-scale assessments. In addition, it tackles the issues relating to Finnish teachers' implementation of inquiry. The results indicate that guided inquiry experiences increase students' cognitive and non-cognitive factors including future career aspirations. Also, teachers' inquiry implementation is highly correlated to their confidence and collaboration.