

**A comparative study of science education at the
primary school level in Finland and Thailand**

Helsinki 2013

Pavinee Sothayapetch

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Abstract

This research aims to compare science education at the primary school level between Finland and Thailand. The study is divided into three sub-studies concerning: 1) a national science curricula analysis at primary school level based on the PISA scientific literacy framework; 2) an analysis of science textbooks on the electric circuit lesson at grade 6; and 3) interviews with primary school teachers regarding Pedagogical Content Knowledge (PCK) and General Pedagogical Knowledge (GPK) on the electric circuit lesson at grade 6. These three sub-studies may reflect the holistic science education of the two countries in this comparative study between them.

The main research methodology used in this study is the comparative approach and a content analysis technique was used in all three sub-studies. All textual and pictorial information from the science curricula at primary school level, including science textbooks, the electric circuit lesson and the teachers' transliterations, were analysed following the inductive and deductive content analysis. Semi-structured interviews were employed for the collection of the interview data. Altogether, six experienced primary school teachers participated—three Finnish teachers in Helsinki and three Thai teachers in Bangkok. In addition, a quantitative method was used to describe the findings from the qualitative approach through percentages, bar charts and a Pearson's chi-squared test.

The main findings revealed that Finnish science education strongly emphasised conceptual knowledge (according to all three sub-studies) while the Thai science education emphasised procedural knowledge. For example, the Thai curriculum was closer to the PISA framework than was the Finnish curriculum. The Thai curriculum emphasised the scientific process and the Finnish curriculum focused on the concepts and contexts, rather than the process. The Thai textbooks emphasised procedural knowledge, while conceptual knowledge was emphasised mostly in the Finnish textbooks. Lastly, in the interviews the Finnish teachers emphasised the teaching of concepts through textbooks and computer materials. The Thai teachers emphasised the teaching and learning of procedural knowledge and consequently used more experimentation, along with authentic materials in the school laboratory.

Both Finnish and Thai curriculum designers and textbook authors could apply the findings of this comparative research. In addition to the similarities and differences, the comparison revealed particular avenues that could be developed in science education. For example, curriculum planners and science educators, not only in Finland and Thailand but also in other countries

in the future, may better recognize what should be emphasised in the science curriculum, especially from the perspective of the PISA Scientific Literacy Framework as the international student assessment. Furthermore, textbook authors may apply some of the comparative results of this research to produce high-quality textbooks based on a heightened awareness of the importance of the curriculum and of teachers' ideas. Finally, as regards practical issues in the classroom, the Thai teachers may learn how to avoid disciplinary problems from their Finnish counterparts. Further, the Finns may learn from the Thai teachers how to organise laboratory activities for relatively large sized classes and how to balance the learning of conceptual and procedural knowledge.

Keywords: comparative study, science curriculum, science textbook, general pedagogical knowledge, pedagogical content knowledge, primary school level, electric circuit, content analysis, Finland, Thailand

Pavinee Sothayapetch

Peruskoulun alaluokkien luonnontieteiden opetus Suomessa ja Thaimaassa: Vertaileva tutkimus

Tiivistelmä

Tutkimuksen tavoitteena on vertailla luonnontieteiden opetusta peruskoulun alaluokilla Suomessa ja Thaimaassa. Tutkimus jakautuu kolmeen osatutkimukseen: 1) kansallisten perusopetuksen luokkien 1-6 opetussuunnitelma-asiakirjojen analysointi PISA-viitekehyksessä; 2) perusopetuksen kuudennen luokan kahden oppikirjan virtapiiriä koskevien osuuskien analysointi; ja 3) luokanopettajien haastattelu koskien heidän käyttämänsä pedagogista sisältötietoa ja yleistä pedagogista tietoa tilanteessa, jossa opetetaan virtapiiriin liittyviä asioita luokalla 6. Näiden kolmen osa-tutkimuksen avulla saadaan kokonaisvaltaista tietoa luonnontieteiden opetuksesta vertailumaissa.

Tutkimusmenetelmänä kaikissa kolmessa osatutkimuksessa on käytetty vertailevan tutkimuksen lähestymistapaa ja klassista sisällönanalyysia. Teksti- ja kuvallinen informaatio kansallisissa opetussuunnitelma-asiakirjoissa ja oppikirjoissa sekä opettajien litteroidut haastattelut analysoitiin induktiivisella ja/tai deduktiivisella sisällön analyysilla. Haastatteluaineisto hankittiin puolistrukturoidulla haastattelulla. Haastatteluun osallistui kolme luokanopettajaa Suomesta ja kolme Thaimaasta pääkaupunkiseuduilta. Sisällön analyysin tuloksia käsiteltiin myös kvantitatiivisella otteella, kuten Pearsonin khin neliötestillä, ja havainnollistettiin pylväsesityksin.

Tutkimuksen päätulos on, että suomalainen ala-luokkien luonnontieteiden opetus painottaa käsitteellistä osaamista ja thaimaalainen menetelmällistä osaamista. Tämä tuli selkeästi esille kaikissa kolmessa osatutkimuksessa. Thaimaalainen opetussuunnitelma oli lähempänä PISA viitekehystä kuin suomalainen opetussuunnitelma. Thaimaalainen opetussuunnitelma painotta prosessia ja suomalainen käsitteitä ja konteksteja, joissa käsitteitä kohdataan. Myös haastattelussa suomalaiset opettajat korostivat käsitteiden opettamisen tärkeyttä oppikirjoihin ja digitaalisiin oppimateriaaleihin tukeutuen. Thaimaalaiset opettajat puolestaan painottivat prosessin oppimista ja niiden oppimista tukevien tutkimusten tekemistä koululaboratoriossa.

Opetussuunnitelman ja oppikirjojen kirjoittajat voivat käyttää hyväksi vertailevan tutkimuksen tuloksia. Kahden maan opetussuunnitelmien ja oppikirjojen samankaltaisuuksien ja erojen tunnistamisen lisäksi tutkimuksen tuloksia voidaan käyttää luonnontieteiden opetuksen kehittämiseen kummassakin maassa. Esimerkiksi opetussuunnitelmien laatijat voivat pohtia tämän tutkimuksen tulosten valossa, mitä ja millä tavalla opetussuunnitelmassa korostetaan ja millä tavalla PISA-tutkimuksen viitekehys ja arviointi on linjassa tai ei ole linjassa opetussuunnitelman kanssa. Oppikirjan kirjoittajat voivat tukeutua oppikirjoja koskevan osatutkimuksen lisäksi

myös opetussuunnitelmatutkimuksen tuloksiin ja opettajien haastatteluissa esille tulleisiin opettajien tarpeisiin. Thaiopettajat voivat oppia suomalaisilta opettajilta keinoja työrauhan ylläpitämiseen ja suomalaiset opettajat thaimaalisilta opettajilta keinoja oppilastöiden tekemiseen suuressa luokassa ja lisäksi kuinka löydetään parempi tasapaino käsitteellisen ja menetelmällisen tiedon oppimisen välille.

Avainsanat: vertaileva tutkimus, luonnontieteiden opetussuunnitelma, oppikirja, yleinen pedagoginen tieto, pedagoginen sisältötieto, virtapiiri, sisällön analyysi, Suomi, Thaimaa

มหาวิทยาลัยเฮลซิงกิ

คณะพหุศึกษาศาสตร์

ภาควิชาครุศึกษา

รายงานการวิจัยเล่มที่ 348

ภาวิณี ไสยาะพีซอร์

การศึกษาเปรียบเทียบด้านวิทยาศาสตร์ศึกษาในระดับประถมศึกษาระหว่างประเทศฟินแลนด์และประเทศไทย

บทคัดย่อ

รายงานการวิจัยเล่มนี้มีวัตถุประสงค์เพื่อศึกษาเปรียบเทียบวิทยาศาสตร์ศึกษาในระดับประถมศึกษาระหว่างประเทศฟินแลนด์และประเทศไทย โดยการวิจัยถูกแบ่งออกเป็น 3 งานวิจัยย่อยๆ ได้แก่ 1) การวิเคราะห์หลักสูตรวิทยาศาสตร์ชาติในระดับประถมศึกษา 2) การวิเคราะห์ตำราเรียนในบทเรียนเรื่อง วงจรไฟฟ้า ระดับชั้นประถมศึกษาปีที่ 6 3) การสัมภาษณ์ครูระดับประถมศึกษาเพื่อให้ได้รับความคิดเห็นเกี่ยวกับความรู้ด้านศาสตร์การสอนต่างๆ ไป (General Pedagogical Knowledge: GPK) และความรู้ด้านศาสตร์การสอนในเนื้อหาวิชา (Pedagogical Content Knowledge: PCK) ในการสอนบทเรียนเรื่องวงจรไฟฟ้าระดับชั้นประถมศึกษาปีที่ 6 สำหรับงานวิจัยย่อยทั้ง 3 เรื่องตามที่กล่าวมาจะสะท้อนให้เห็นถึงองค์รวมด้านวิทยาศาสตร์ศึกษาในการศึกษาเปรียบเทียบระหว่างสองประเทศได้เป็นอย่างดี

ระเบียบวิธีการวิจัยหลักที่ใช้คือ วิธีการศึกษาเปรียบเทียบ สำหรับงานวิจัยย่อยทั้ง 3 งานนั้นจะใช้เทคนิคการวิเคราะห์เนื้อหา กล่าวคือ รายละเอียดของข้อความและรูปภาพทั้งหมดจากหลักสูตรวิทยาศาสตร์ระดับชาติ จากคำสัมภาษณ์ของครูและจากตำราเรียนวิทยาศาสตร์ของทั้งสองประเทศจะถูกทำการวิเคราะห์ด้วยเทคนิคการวิเคราะห์เนื้อหาทั้งแบบอุปนัยและนิรนัย สำหรับข้อมูลจากการสัมภาษณ์ครูนั้น การศึกษาแบบรายกรณีนำมาใช้เพื่อให้ได้ข้อมูลจากการสัมภาษณ์ดังกล่าว โดยครูระดับประถมศึกษาผู้ที่มีประสบการณ์ด้านการสอนจำนวน 6 คน ประกอบด้วย ครูฟินน์ที่ทำการสอนอยู่ที่โรงเรียนในเขตเฮลซิงกิจำนวน 3 คน และครูไทยที่สอนอยู่ที่โรงเรียนในเขตกรุงเทพฯจำนวน 3 คน ได้รับการสัมภาษณ์แบบกึ่งมีโครงสร้าง นอกจากนี้วิธีการเชิงปริมาณได้แก่ รัยละเอียดแผนภูมิแท่งและการทดสอบค่าไคสแควร์ถูกนำมาใช้ในการวิเคราะห์ผลด้วย

ข้อค้นพบหลักของการวิจัยนี้แสดงให้เห็นว่า วิทยาศาสตร์ศึกษาของประเทศฟินแลนด์นั้นเน้นค่อนข้างมากเกี่ยวกับความรู้เชิงโมโนทัศน์ (Conceptual Knowledge) ในขณะที่ในประเทศไทยนั้นเน้นความรู้เชิงกระบวนการ (Procedural Knowledge) ซึ่งเห็นได้จากผลการวิจัยย่อย 3 เรื่อง ตัวอย่างเช่น หลักสูตรวิทยาศาสตร์ของประเทศไทยมีความใกล้เคียงกับกรอบแนวคิดของพีซ่า (PISA) มากกว่าประเทศฟินแลนด์ โดยการเน้นกระบวนการทางวิทยาศาสตร์แต่ของประเทศฟินแลนด์นั้นเน้นในเรื่องของโมโนทัศน์และบริบทเป็นสำคัญ ส่วนการวิจัยเรื่องตำราเรียน ตำราเรียนของประเทศไทยนั้นจะเน้นความรู้เชิงกระบวนการแต่ของประเทศฟินแลนด์นั้นเน้นความรู้เชิงโมโนทัศน์เป็นสำคัญ เช่นเดียวกับครูสัมภาษณ์ครูในระดับประถมศึกษาพบว่า ครูฟินน์สอนเรื่องวงจรไฟฟ้าด้วยการเน้นการเรียนการสอนเชิงโมโนทัศน์โดยการใช้ตำราเรียนและสื่อคอมพิวเตอร์ต่างๆ ให้แก่นักเรียน ในขณะที่ครูไทยให้ความสำคัญกับการเรียนการสอนเชิงกระบวนการโดยการสอนแบบการทดลองในห้องปฏิบัติการวิทยาศาสตร์

และการใช้สื่อของจริง เช่นเดียวกับการวิจัยเรื่องตำราเรียนตำราเรียนของประเทศไทยนั้นจะเน้นความรู้เชิงกระบวนการ แต่ของประเทศฟินแลนด์นั้นเน้นความรู้เชิงมโนทัศน์เป็นสำคัญ

ผู้ออกแบบหลักสูตรและผู้เขียนตำราเรียนของทั้งสองประเทศสามารถนำผลการวิจัยเชิงเปรียบเทียบนี้มาปรับประยุกต์ใช้ได้อย่างเหมาะสม นอกจากนี้ความเหมือนและความแตกต่างของการศึกษาเปรียบเทียบแสดงให้เห็นถึงแนวทางที่เป็นไปได้ในการพัฒนาวิทยาศาสตร์ศึกษาซึ่งเป็นพื้นฐานของงานวิจัยนี้ ตัวอย่างเช่น ผู้ออกแบบหลักสูตรและนักการศึกษาทั้งหลายไม่เฉพาะแต่ประเทศไทยหรือประเทศฟินแลนด์เท่านั้นแต่หมายถึงประเทศอื่นๆ ด้วยที่จะตระหนักว่าอะไรบางอย่างที่ควรคำนึงถึงในหลักสูตรวิทยาศาสตร์ตามมุมมองของกรอบแนวคิดด้านความสามารถในการอ่านเขียนด้านวิทยาศาสตร์ (PISA Scientific Literacy Framework) ซึ่งถือว่าเป็นกรอบสำคัญในการประเมินผลนักเรียนในระดับนานาชาติ รวมทั้งผู้เขียนตำราเรียนสามารถนำผลการวิจัยเปรียบเทียบนี้ไปประยุกต์ใช้ในการผลิตตำราเรียนที่มีคุณภาพให้เหมาะสมกับนักเรียนในอนาคตได้ โดยตระหนักถึงความสำคัญของหลักสูตรและความคิดเห็นของครูเป็นอันดับแรก สุดท้ายนี้กล่าวถึงการทำน้อมนำมาปฏิบัติใช้ในระดับชั้นเรียนให้บรรลุผล เช่น ครูไทยสามารถเรียนรู้จากครูฟินแลนด์ว่าจะหลีกเลี่ยงการเกิดปัญหาระเบียบวินัยในชั้นเรียนได้อย่างไร รวมถึงครูฟินแลนด์เรียนรู้จากครูไทยในการจัดกิจกรรมการเรียนการสอนที่ห้องปฏิบัติการทางวิทยาศาสตร์ที่ชั้นเรียนมีขนาดใหญ่ได้อย่างไรและจะทำการเรียนรู้เชิงมโนทัศน์และการเรียนรู้เชิงกระบวนการเกิดความสมดุลกันสำหรับนักเรียนในการเรียนรู้

คำสำคัญ: การศึกษาเปรียบเทียบ, หลักสูตรวิทยาศาสตร์, ตำราเรียนวิทยาศาสตร์, ความรู้ด้านศาสตร์การสอนทั่วไป, ความรู้ด้านศาสตร์การสอนในเนื้อหาวิชา, ระดับประถมศึกษา, วงจรไฟฟ้า, การวิเคราะห์เนื้อหา, ประเทศฟินแลนด์, ประเทศไทย

Preface

I received a scholarship from Thailand's Commission on Higher Education under the administration of the Royal Thai Government to continue my PhD programme here in Finland. This dissertation can benefit both in Finnish and Thai science education. I hope that the comparative results of each sub-study can be applied appropriately in the current situation in both Finland and Thailand to greater or lesser degrees. This comparative research was rather challenging for me as a researcher with different backgrounds, contexts, cultures, traditions, values, and languages in Finland. However, I have learned a lot from Finland during my PhD research, particularly regarding academic life. Finland is well known for having the best education system and a high-quality teacher education program; therefore, it has been a good opportunity for me to investigate the science curriculum, science textbooks and Finnish teachers. The research findings remind me as a lecturer to recognise which aspects of science education should be developed further, what should be prioritised in science education and what else I can explore in future research.

Helsinki, October 31th
Pavinee Sothayapetch

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This dissertation provides me a great opportunity, once in my life, in pursuit of a real academic community. A result of this accomplishment is from many individuals. A great many people have contributed to its outcome, although only my name appears on the cover of this dissertation. I owe my gratitude to all those people who have made this dissertation possible.

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1 Introduction

The Finnish education system is considered to be one of the best in the world and it supports people to learn “key” competences in order to operate in the modern knowledge society. Ruzzi (2005) analysed the education of children in *Organisation for Economic Cooperation and Development* (OECD) nations and found that Finnish children had the highest overall scores in OECD assessments. In 2002, the release of the first *Programme for International Student Assessment* (PISA) results has drawn the attention of many countries to the Finnish education system. One issue of interest is the excellent results achieved by 15-year-old Finnish students (Väljjarvi, Linnakylä, Kupari, Reinikainen & Arffman, 2002; Väljjarvi, Kupari, Linnakylä, Reinikainen, Sulkunen, Törnroos & Arffman, 2007). These students achieved scores in reading, mathematics and scientific-literacy assessment that were among the highest in OECD countries in 2000, 2003, 2006 and 2009 (OECD, 2007; 2010). Whereas, Thai students have had less success in the PISA. For example, Thai students scored 130 points less than Finnish students on the science scale in 2009. Not only the high scores but also the low variation of performance in results is an important outcome of the Finnish education policy. The total variation in the PISA 2006 science performance was almost the same in Finland (0.60) and in Thailand (0.60). However, it becomes more interesting if the variation in scores is divided to show the variation of performance within schools and between schools. Then, the variation between schools is very low in Finland (0.04) and relatively high in Thailand (0.30) (Hautamäki, Harjunen, Hautamäki, Karjalainen, Kupiainen, Lavonen, Pehkonen, Rantanen, & Scheinin, 2008, p. 54) In addition to the release of PISA results by the OECD, there have been many secondary analyses of PISA data and other PISA related research. For example, Beese and Liang (2010) conducted a comparative study by using the PISA 2006 data from three countries– the United States, Canada and Finland in order to investigate how school resource indicators such as teacher qualifications, school resources and school type, as well as student level indicators such as socioeconomic status and family resources impact science achievement. This study found that education policy in Finland ensures that all students have the proper school resources such as adequate equipment in the science laboratory.

There is no tradition of private tutoring or evening schools in Finland as there is in many Asian countries. Finnish parents trust school and teachers and do not buy additional educational services. Moreover, the number of schooldays and school lesson hours in Finland is among the lowest in the OECD countries (Sahlberg, 2011). These findings indicate that Finnish com-

prehensive schools are very similar and the teachers are very effective. Consequently, this research topic emerged from my curiosity about Finnish science education. One way to investigate the reasons for this success is to examine the education system, particularly concentrating on the science national-level curriculum, science textbooks and the knowledge teachers employ when planning and teaching science. These can be considered as important factors that influence students' learning and instruction, and each factor plays a vital role in their education.

Many factors can affect the quality of a country's education system. First, its national-level curriculum has an influence on schooling and education in general. This curriculum stipulates a country's goals for education, the implementation of instruction, learning objectives and core contents of education, student assessment, time allocation for each school subject and other considerations. As the United States Department of Education (2000) has recommended, the curriculum specifies the direct implications for how course content is covered, how much time is available for each topic and what and how students should learn. Such features can reflect both the quality of the school and the pedagogy of a teacher. Because a country's national-level curriculum is a major plan to educate people, every school must embrace it as a crucial framework for education provision.

The National Curriculum is a framework used by all maintained schools. Its purpose is to set out the subjects taught, the knowledge, skills and understanding required in each subject. It is a measure of the attainment or standards expected in each subject. The framework is designed to enable teachers to measure pupils' progress, and teachers are expected to carry out assessments as part of regular activity, and also at the end of what are referred to as 'Key Stages' (Davey & Fuller, 2010, p. 11).

Second, a subject curriculum in formal education is a master plan that defines the set of common courses, as well as the aims for learning and content, time allocation, learning resources and so on in the instructional process for that subject. Science is a core subject in science curricula for primary and secondary schools and includes physics, biology, chemistry environmental and natural studies, geography, and health education. A school's science curriculum is usually developed centrally (Sharifah Maimunah Syed Zin, 2003). Moreover, it enables students to learn through the process and methods of scientific inquiry to gain a scientific perspective and sensibility, as well as a preliminary understanding about the nature of science and the relationships between science, technology and society (APEC, 2006).

Consequently, the instructional process occurring in schools is directly related to the schools' implementation of their science curriculum. Brandsford,

Brown and Cocking (2000) suggested that teachers are central in enhancing learning in schools. Therefore, teachers are the third key factor for students' academic achievement. Teachers typically work with a whole class, trying to reach all their students with respect to the information they are trying to teach (Joyce, Calhoun & Hopkins, 2002). Besides, students are the 'product' of their teachers' work (Alexiadou, 2001) and the outputs representative of classroom processes reflect the teachers' effectiveness (Goe, Bell & Little, 2008). The 'output' definition of an effective teacher has a close link to the idea of educational accountability, where nationwide testing is organised to recognise both effective and ineffective schools and teachers (Evers & Walberg, 2004).

Teacher education can be one indicator of the success or failure of a country's education system. In order to train effective teachers, most of the highest achieving nations have reformed their teacher education to ensure that candidates are the products of intense teacher training programmes before they enter the profession (Darling-Hammond, Wei & Andree, 2010). In Scandinavian countries such as Finland, programmes also include extensive coursework in content-specific pedagogy and a thesis researching an educational problem in the schools. Finland's teacher training programmes reflect the high status of teachers and the professional reputation of the teaching profession (Chung, 2008, p. 152). Teacher education programmes all lead to a master's degree in education, which is the accepted formal training for Finnish teachers, including those at the primary school level. A three-year programme at a teacher training college was standard for primary school teacher training until the late 1970s when programmes were extended to four-years, and finally, five-year programmes in universities (Sahlberg, 2007). In the programme, school teachers have to concentrate on pedagogy in a master's degree, whereas subject teachers have a master's degree within their specific subject (Chung, 2008). Differently, in Thailand, teacher education has taken place in a more open system with several types of institutions (Chanbanchong, 2010). There are a few open universities that also provide in-service training through distance education. These are mainly formal courses that result in university credit. Teacher education courses are five-year programmes leading to a bachelor's degree (Office of Commercial Services, 2002). The curricula of Thai teacher training programmes depend on each institute organising courses for its students.

Therefore, from the previous paragraph, it is clear that teachers' knowledge of pedagogy and subject content must also be taken into account as one of the teacher factors. Gurney (2007) suggested that one key factor involves teachers' knowledge, enthusiasm and responsibility for learning. Teachers' knowledge is connected to their students' learning, and an important question

involves what knowledge is considered adequate and appropriate (Burgess, 2009). One widely used conceptualisation of teachers' knowledge was proposed by Shulman (1986), who emphasised comprehension, reasoning, transformation and reflection as important characteristics of a teacher. Due to the fact that the curriculum emphasises the learning of knowledge and skills or competencies, the teacher needs to understand the structures of content knowledge and conceptual organisation so that students are able to learn relevant knowledge. Therefore, the teacher is responsible for content knowledge (CK). "The first source of the knowledge base is content knowledge—the knowledge, understanding, skill, and disposition that are to be learned by school children" (Shulman, 1987, p. 8–9). Chi and Ceci (1987) demonstrated that by the 1980s, cognitive developmentalists had proposed that content knowledge played a critical role in children's learning and cognitive development.

In addition to CK, other aspects of teacher knowledge are important for teachers and successful teaching, including pedagogical content knowledge (PCK), general pedagogical knowledge (GPK) and curriculum knowledge. The main reason relates to the idea that CK is not sufficient; more supportive knowledge is required for teachers' instruction because when teachers have a depth of understanding with respect to particular subjects, it is their personal duty to convey the subject matter to students, emphasising what is essential about it, how to transform the content knowledge in an unconstrained way of teaching and learning and in what way they can facilitate and enhance the students' understanding of the content knowledge. Consequently, textbooks as a main source of content knowledge are another key factor in the teaching and learning process for both teachers and students.

In terms of PCK and GPK as two categories of teacher knowledge, both can be differentiated by their unique purpose. Shuman (1987) concluded that GPK had special reference to those broad principles and strategies of classroom management and organisation that appear to transcend subject matter. Hativa, Barak and Simhi (2001) also conducted a study focusing on GPK, proposing a definition of GPK as involving pedagogical principles and classroom strategies with no relationship to subject matter. As aforementioned regarding subject matter, knowledge transformation and conveyance to students, PCK has a vital function for this idea. "PCK implies a transformation of subject matter knowledge, so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice", as mentioned by van Driel, Verloop and de Vos (1998, p. 675). Teachers need to have knowledge not only on the specific content they are

teaching, but also regarding what students need in terms of their varied interests and abilities (Barnett & Hodson, 2000).

In order to compare science education at the primary school level in both Finland and Thailand, a general description of both countries' basic education systems is necessary. In Finland, the education system is comprised of a nine-year basic education (comprehensive school), free of charge and with free meals served to all full-time students. The education system is separated into three main types of education (FNBE, 2004):

1. Pre-primary education (6 years old) is preceded by one year of voluntary participation for children.
2. Basic education (7 to 19 years old) encompasses primary (7 to 13 years old), lower secondary (13 to 16 years old) and upper secondary education levels (16 to 19 years old).
3. Higher education system (20 years old and above) comprises universities and polytechnics, in which the admission requirement is a secondary general or vocational diploma.

Universities (20 years old and above) offer bachelor's, master's, licentiate and doctoral degrees.

Polytechnics (20 to 24 years old): A polytechnic degree requires 3.5–4.5 years of full-time study. The requirement for polytechnic master's programmes is a polytechnic degree or equivalent, plus a minimum of three years of work experience in the field concerned.

Adult education is available at all levels; moreover, special needs education is integrated into regular education as much as possible.

The general goals for Finnish basic education are as follows:

- To support pupils' growth towards humanity and ethically responsible membership in society.
- To provide pupils with the knowledge and skills needed in life.
- To promote learning and equality in society.
- To guarantee equality in education throughout the country.

In Thailand, the education system consists of 12 years of free basic education: six years of "Prathom" (primary education, P1 to P6 or grades 1 to 6 in Finland) and six years of "Mattayom" (secondary education or grades 7 to 12 in Finland). Enrolment in the basic education system begins at the age of six years old. There are three types of education for Thai people (Ministry of Education, 2007):

1. Formal education is comprised of early-year education (3 to 5 years old), basic education (6 to 17 years old) and vocational and technical education (15 to 19 years old), which is conducted at three levels: upper secondary (receive the Lower Certificate of Vocational Education), post secondary (receive a Diploma or Vocational Associate Degree) and university level

(receive a Degree), higher education (age 16 to) is provided at universities and colleges.

2. Non-formal education has long given priority to adults. It provides life-long learning opportunities to the out-of-school population.
3. Informal education entails developing a learning society to promote the idea that learning can also take place outside the formal space of the classroom. A network of over 800 libraries, at district and provincial levels, together with a network of 15 science museums support informal learning in Thailand.

For special needs education, e.g. gifted and talented children, alternative education, education for the disadvantaged and informal education, the Basic Education Core curriculum can be adjusted to suit the situation and context of each group.

Thailand's national core curriculum sets broad goals for developing learners from primary education grade 1 to secondary grade 6 in five areas: (a) morality, ethics, desirable values, self-esteem, etc.; (b) knowledge and skills for communication, thinking, problem-solving, etc.; (c) good physical and mental health; (d) patriotism, awareness of responsibilities and commitment as Thai citizens and members of the world community; (e) awareness of the need to preserve all aspects of Thai culture and Thai wisdom.

As this research involves a comparative approach, differences between the countries, such as their cultures, values, traditions, thought patterns, environments and languages could be taken into the consideration (Hantrais & Mangen, 1996). In the national level curriculum, values and cultural issues are addressed. For example, educational equality and a culture of trust are important aims in Finnish education. Educational equality is most essential in Finnish education policy, which states students should have equal opportunities to learn, and thus free education, including books, meals and health care is available. Schools do not select their students; instead there are school districts in which every student can learn. For this reason, parents have the possibility of selecting a school of their choice (Laukkanen, 2008; Sahlberg, 2010; Niemi, Toom & Kallioniemi, 2012). One important consequence of the equality policy is effective special education, which aims to prevent students from dropping out and to support the learning of all students. According to this policy, teachers should not consider students in their class as one group; instead, teaching should be adjusted to meet the individual needs of each student (Jahnukainen, 2011). The *basic education act 628/1998: Amendments up to 1136/2010* emphasise different levels of support for individual students (Section 31a).

Similar to the Finnish education system's equality policy, in Thailand, the National Education Act B.E. 2542 (1999) (ONEC, p. 6) in Section 10 stipulates that in the provision of education, all individuals shall have equal rights and opportunities to receive basic education provided by the State for the duration of at least 12 years. Such education, provided on a nationwide basis, shall be of high quality and free of charge. Persons with physical, mental, intellectual, emotional, social, communication and learning deficiencies shall all have the rights and opportunities to receive basic education. Education for specially gifted persons shall be provided in appropriate forms in accordance with their competencies.

As noted previously, another characteristic of Finnish education is its culture of trust (Sahlberg, 2007). Education authorities and national-level education policymakers trust professional teachers who know, together with principals, headmasters and parents, how to provide the best education for children and adolescents in a certain district. Finnish schools and teachers have been responsible for choosing learning materials and teaching methods since the beginning of the 1990s when the national level inspection of learning materials was terminated. Moreover, there have been no national or local school inspectors since the late 1980s. Teachers are valued as professionals in curriculum development, teaching and assessment at all levels (FNBE, 2004) and the teaching profession in Finland has always enjoyed great public respect and appreciation (Simola, 2005). The Finnish education culture is closely aligned to the opinions of experts arguing for accountability policies.

Trusting schools and teachers is a natural consequence of a generally well-functioning civil society and high social capital. Teachers can take part in a system in which schools and communities are the places where decisions regarding the curriculum and overall arrangement of schooling should be made. Consequently, teachers with high professional and moral qualifications are highly responsible for this function. Therefore, schools seemed to change their new roles in leading change within the culture of trust. Until now, the trust culture has played a significant role in propelling Finland's education system, unlike Thailand, which lacks a culture of trust in the education system. This tends to contribute to Thai teachers' lack of autonomy and independence in their profession.

All of the above-mentioned factors have guided this research. I have researched three perspectives on science education, which all offer a holistic viewpoint for the comparison of Finland's and Thailand's education systems. Therefore, the study is separated into three parts focusing on science education as follows: The comparison analyses of (a) national science curricula at the primary level; (b) science textbooks at the primary school level; (c) the results of primary teachers' PCK and GPK interviews presented in Chapters

4-6. The relationships among those three perspectives illustrate the educational systems' hierarchy. This means, national science curricula are at the policy level, while teachers and the use of textbooks represent an action level (practical classroom). School and classroom levels relate to the curricula and textbooks implementations. If the structure of the education is clear, as described in the national-level curriculum, the principals and teachers are following the national-level curriculum, and the instructional process influences students (Creemers & Reezigt, 1996). Therefore, the process of instruction at classroom level relies primarily on the teachers' role. Bottoms (2001) suggested that teachers have the opportunity to strengthen CK by combining it with instructional methods and what students are expected to learn in the core curriculum.

Teachers tend to favour particular modes of instruction which suit either the personality of the teacher, the materials being used, the expectations of the learners, the prescriptions of school administrators, the subject matter being treated, the preferences of teachers for certain types of classroom process or the teacher's interpretation of the idea of 'instruction' (Beltrán 2012, p. 5).

1.1 Research tasks

This research is comparative in nature. It concentrates on several aspects of science education. The research task is specified based on the research aims and the research report consists of three sub-studies as follows:

1. National science curricula analysis at the primary level in Finland and Thailand.
2. An analysis of Finnish and Thai science textbooks: The electric circuit lesson.
3. Interviews with primary school teachers regarding their PCK and GPK in both Finland and Thailand.

The three sub-studies were conducted similarly in Finland and Thailand:

- The Finnish and Thai national science curricula were analysed and compared using content analysis (Neuendorf, 2002).
- The sixth-grade electric circuit chapters in science textbooks in Finland and in Thailand were analysed utilising content analysis (Neuendorf, 2002). The Pearson's chi-square test was used to compare the outcomes of the content analysis.
- The Finnish and Thai primary teachers were interviewed to evaluate their PCK and GPK in the context of teaching about electric circuits. A semi-structured interview was employed to collect the data. This sub study can

be characterised as a content analysis having features of inductive and deductive analyses (Elo & Kyngäs, 2008). All three sub-studies have been published as journal articles¹.

1.2 Research design

This section presents the research design and methodology used for the research project, including the research aims, questions, main theories and concepts used, and the research tool design. The research is qualitative in nature, utilising content analysis for curriculum documents, textbooks and interview transliterations.

1.2.1 Aim of the research report

This report presents the comparative study of science education in Finland and Thailand through the three main sub-studies mentioned previously. The aim of the study was to understand the similarities and differences in primary school science education in these countries.

1.2.2 Research questions

Specific research questions were refined in order to meet the aims of the study. The first question focuses on the national science curricula and textbooks analyses. The second question is related to the interviews with primary school teachers. All of the main research questions are presented in detail in the sub-chapters of the report. The main research questions are as follows:

1. What are the similarities and differences in primary school science education between Finland and Thailand as regards the science curricula and textbooks used?
2. What are the similarities and differences between Finnish teachers' expressions and Thai teachers' expressions on PCK and GPK while they plan or implement the electric circuit lesson at the grade 6 level?

[1] Sothayapetch, P., Lavonen, J., & Juuti, K. (2013). A comparative analysis of the PISA scientific literacy framework in Finnish and Thai science curricula. *Science Education International*, 24(1), 78–97.

[2] Sothayapetch, P., Lavonen, J., & Juuti, K. (2013). An analysis of science textbooks for grade 6: The electric circuit lesson. *Eurasia Journal of Mathematics, Science & Technology Education*, 9(1), 59–72.

[3] Sothayapetch, P., Lavonen, J., & Juuti, K. (2013). Primary school teachers' interviews regarding pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK). *European Journal of Science and Mathematics Education*, 1(2), 84–105.

1.2.3 Conceptual background

The concepts used in this research will be introduced thoroughly in each chapter of the separate sub-studies. However, the main concepts, models and theories will be explained in general following the three sub-studies.

The main organisational model used for the study of science curricula analysis is the PISA Scientific Literacy Framework of 2006 (OECD, 2006). This framework introduces the knowledge and skills or competencies necessary for operating as an active citizen in the 21st century. Three main aspects — contents, competencies and contexts — are emphasised in the PISA framework as follows.

The PISA framework classifies content knowledge into two sub-categories: knowledge of science and knowledge about science. Competence is defined in terms of an individual's scientific knowledge and use of that knowledge to identify scientific issues; explain scientific phenomena and draw evidence-based conclusions. Contexts are framed within a wide variety of life situations involving science and technology at the personal, social and global levels, such as health, natural resources, environmental quality and hazards (OECD, 2006).

In order to analyse the electric circuit chapters in the Finnish and Thai science textbooks, four main categories were defined by reviewing the literature:

1. Introduction of concepts: The way the concepts are introduced to the students.
2. Type of knowledge: Text and figures emphasise the learning of procedural knowledge or conceptual knowledge.
3. Representations: All the textual and pictorial information in the analysed chapters indicating the types of the figures, pictures or drawings is used to introduce the concepts to the students.
4. Contexts: Concepts in the textbook are presented in different contexts.

Several other minor concepts belonged to each main category as well. Information on the other concepts is provided in Chapter 5, Section 5.3.

The theories used for the interviews of primary school teachers regarding their PCK and GPK issues were grouped into two main theories: PCK and GPK. The PCK and GPK theories were mainly utilised to develop the interview protocol for teachers and for the discussion of the findings. Regarding Shulman's original PCK concept, two aspects play an important role in instruction: content knowledge (CK) and pedagogy. Many scholars have studied PCK. In this study, the concept of PCK proposed by Chick, Baker, Pham

and Cheng (2006) was selected. They separated the PCK into pedagogy and content categories where sub-categories belong to both categories. Pedagogy emphasises the aims for learning, student thinking, students' misconceptions, understanding of procedural knowledge, knowledge of resources and classroom techniques. Content consists of purpose of content knowledge, the evaluation of student learning of conceptual knowledge and representations of concepts. For the concept of GPK, Morine-Deshimer and Kent's (1999) concept of GPK was used significantly in the study. These researchers divided general pedagogical knowledge into three main categories as follows: the instructional models (teaching methods), classroom management and classroom communication. *Classroom management* is consistent with noting general principles of teacher behaviour that promote student achievement. Classroom management focuses on three major components: content management, conduct management and covenant management. *Instructional methods and teaching methods or models* could be grouped into four families based on the concept of Joyce, Calhoun and Hopkins (2002) that share orientations toward human beings and how they learn: the social family, the information-processing family, the personal family and the behavioural systems family. *Classroom communication*, as described by Anderson and Garrison (1998), was adapted in this research report. Moreover, two forms of communication, verbal and non-verbal communication (Johnson, 1999), were applied to Anderson and Garrison's concept as well. Three types of classroom communication were studied: teacher-student interaction, student-student interaction and no interaction.

1.2.4 Research tool design

Semi-structured interviews and theory-driven content analysis (Neuendorf, 2002; Elo & Kyngäs, 2008) of texts (curriculum, textbook, transcribed interview protocol) were used as research and data analysis methods in the study. An interview protocol was designed to gain background information on participating individuals (e.g. name, age, responsibilities and teaching experience), PCK (pedagogy and content) and GPK (classroom management, instructional models and classroom communication), in the context of electric circuit lessons. The interviews were semi-structured, because this approach is flexible enough to consider any relevant issues that the respondents brought up.

The interview protocol was developed based on the literature review and the main concepts were identified for the study. The first interview protocol was tested for the research aims and comprehensive questions in a pilot study. Because the interview was conducted in both countries, the interview content

was the same, but in different languages. For the purposes of this study, I introduced the Thai version to some Thai friends who had been studying in the different fields e.g. physics and forestry here in Finland to develop more comprehensible questions such as the language use. The English version of the interview protocol was introduced to Finnish colleagues to ensure that the same questions were being addressed. The interview protocol was revised after receiving feedback and comments on the interview protocol (see Appendix A).

Examples of revised questions:

- How do you support students' learning of procedural knowledge when teaching them about electric circuits?
- The phrase 'procedural knowledge' seemed to be difficult for teachers to understand. Therefore, I modified the question to the following: When teaching students about electric circuits, how do you teach your students to connect a simple electric circuit?
- What about your teaching style? Did you let students construct the knowledge on their own, or did you tell them directly? In addition, how do you start teaching the lesson on electric circuits?

Both questions had the similar aim of clarifying the teaching methods used. The two questions were condensed to one as follows. How do you teach the electric circuit lesson to students?

The complete version of the interview script was completed after pilot testing. The real interviews took place the first time in January 2011 in Thailand, and then in September 2012 in Finland. Altogether, six experienced primary school teachers took part in the interviews; three Finnish primary school teachers in Helsinki and three Thai primary school teachers in Bangkok. The interviews are described further in Chapter 6, Section 6.3

1.2.5 Data analysis

The aim of data analysis in this comparative study was to make comparisons across different contexts, cultures and situations in more than one country. The main advantage of this is that it provides an in-depth examination of national contexts, allowing the researcher to tap into cross-country variation, a feature that is impossible when analyses involve at least two countries. For example, Nevalainen and Kimonen (2009) conducted a comparative study on teacher identity and curriculum change, and teacher competences in England and Finland. As a researcher, I had to consider how the data analyses from

the three separate studies were performed and how to present the results across two countries. Consequently, the theories or concepts used for my analyses were important for my comparative study in terms of the categorising and contextualising strategies I employed. Maxwell (2005) proposed features of the two strategies: (a) categorising strategies attempt to generalise and abstract by generating concepts and even theories from the raw data; (b) contextualising strategies attempt to treat the data as a coherent whole and to retain as much of the raw data as possible to capture the whole context. Based on the three sub-studies in this research, several theories and concepts were used in the context of both strategies.

Furthermore, Weber (1990) stated that content analysis refers to a method of transforming the symbolic content of a document, such as words or images, from a qualitative, unsystematic form into a quantitative, systematic form. The qualitative content analysis in this study is represented by three kinds of data: information in the science curricula, science textbooks and teachers' transliteration. The analysis has both deductive and inductive elements. The science curricula and textbooks were analysed according to the concept of Weber (1990) and Neuendorf (2002). For the analysis of interview data, I followed the ideas of Elo and Kyngäs (2008).

1.3 Structure of the research report

The theoretical framework of the research report will be introduced in the following chapter (Chapter 2). In addition, all the literature related to the research report is reviewed in the theoretical framework chapter to support readers in following the concepts and theories holistically, the trends in each research topic, previous studies on each topic and the gap between the previous and present studies on that topic. After the literature review, the methodology used for the research report is introduced in Chapter 3. Finally, the comparative study chapters (Chapters 4-6) will answer to the research questions.

The comparative study is divided into three chapters (Chapters 4-6) based on the three main perspectives on science education or implementation of the curriculum at the primary school level. Chapter 4 presents the comparison between Finnish and Thai science curricula at the primary school level. The analysis was conducted following the PISA Scientific Literacy Framework of 2006. In Chapter 5, an analysis of electric circuit chapters in science textbooks provides important information on how textbooks introduce concepts. All information in the chapters was analysed according to four categories: the introduction of concepts, the knowledge type, representations and contexts. Then, Chapter 6 reports on primary school teachers' PCK and GPK based on

the interviews conducted with primary school teachers in Finland and in Thailand. The outcomes of the study reflect the teachers' implementation of their teaching process and express their ideas concerning PCK and GPK in the context of electric circuit teaching.

Finally, Chapter 7 describes the trustworthiness of the research, and Chapter 8 presents the discussion and conclusion.

2 Theoretical framework

This chapter introduces the theoretical framework used in the research. According to Robson (2002), the theoretical framework — the system of concepts, assumptions, expectations, beliefs and theories that support and inform the research — is a key part of the research design. Accordingly, for the homogeneity of the research, the theoretical framework is the structure that holds the theory of a research study. The literature relating to this research report is described in Section 2.1.

To propose the fundamental idea in this chapter, the four-step framework described in Figure 1 was used. According to the diagram, the first two steps begin with the national science curricula as a master plan for providing science education in Finland and Thailand. For this reason, the analysis of the science curricula holds analysis of curricula in the frame of the PISA Scientific Literacy Framework of 2006 (OECD, 2006). In Chapter 4, Section 4.2 explains the reason for selecting this framework for analysis. The results of the science curricula analysis provide information on the similarities and differences between the two countries in terms of three main aspects of the PISA Scientific Literacy Framework: competences, contents and contexts.

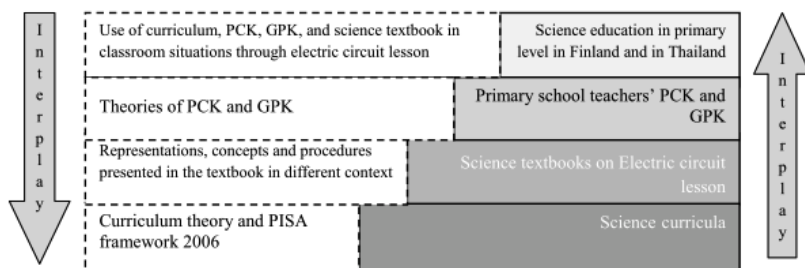


Figure 1. The theoretical framework of the research report.

The theoretical framework in Figure 1 is close to the *Trends in International Mathematics and Science Study* (TIMSS) curriculum framework (Schmidt, Raizen, Britton, Bianchi, & Wolfe, 1997). According to the TIMSS framework, the *official* science curriculum is communicated through national level documents. This official curriculum, together with supporting material such as textbooks, is referred to as the *intended* curriculum. According to Cuban (1992) an intended curriculum organises the body of knowledge that students need to learn and illuminates, at least to some extent, the methods that will be used during instruction. Teachers interpret and modify the in-

tended curriculum according to their perceptions of the needs and abilities of their classes, and this evolves into the *implemented* curriculum. In this implementation, they employ their subject matter, pedagogy, and pedagogical content knowledge. However, this implemented curriculum is not identical to the intended curriculum. The *achieved* curriculum, which includes knowledge, skills and attitudes that are truly learned, is not the focus of this study.

Next, I focused on primary teachers who teach science according to the curricula and textbooks. The aim was to identify what knowledge teachers apply when they teach according to the curricula. The PCK and GPK theories have been used while planning and analysing the interviews to reflect on teachers' PCK and GPK. In fact, PCK and GPK are known to be important domains of teachers' knowledge; they convey the curricula to shape and form the teaching and learning process to meet the education goals specified. The interviews of grade 6 teachers in Finland and Thailand mainly focused on the teaching of electric circuits in the classroom, including teaching methods, classroom communication and classroom management. Textbooks are an important tool both for students' learning and teachers' instruction. Therefore, I decided to focus on one separate study of science textbooks. The aim was to analyse how the science textbooks present information on electric circuits to grade 6 students. Many ideas and concepts from other studies are therefore applied intensively as the analysis concepts.

The fourth step in the diagram is from the results of the step 1–3 processes. Step 1 represents the policy level in the case of the national science curricula, which defines nearly everything related to providing science education such as science goals, content, time allocation, students' assessment and learning materials; it is taken to be an instructional framework. Therefore, to understand how the science curriculum is either effective or ineffective, teachers are concentrated on their instruction, which represents the action level. Consequently, science textbooks are key resources in teaching and learning process as regards in what way the textbook content is introduced, how the content supports students' knowledge and how teachers can apply the content to contexts related to students' lives.

To describe the diagram in greater detail, on the right side, the portion shaded in grey represents the work outline for the study, and the final step (or fourth step) is the aim of the research report — science education at the primary school level in Finland and Thailand. On the left side, the information in the dashed line illustrates the concepts and theories used in each working step. Moreover, the two arrows emphasise the interplay of every step from the top to the bottom step or from the bottom to the top step. All steps affect each other in a cyclical and interdependent manner.

The description of the theoretical framework above clarifies the main concepts and theories used in this research as well as how the three main studies are integrated homogeneously in the research report.

2.1 Literature review

In this sub-section, a literature review related to the research project is presented. First, a literature review of the national science curricula at the primary school level is discussed. The second topic is the literature related to textbooks. Finally, teacher knowledge, with a particular emphasis on PCK and GPK is presented.

2.1.1 Science curricula at the primary school level

Science teaching is a crucial part of the basic education curricula in many countries. Due to the fact that science itself relates to human beings' lives, i.e. everyday life, career, tools and equipment, as well as many products, these facilities from science knowledge blend with creative thinking and the other sciences to assist people in thinking systematically, creatively and critically. As such, the science curriculum plays a major role in science education provision in schools. The national-level curriculum in science describes what and how a teacher should teach science, or what a student should learn. Descriptions of learning outcomes are increasingly used and have been considered an important basis for the quality of science education. However, the descriptions vary, as well as how they are written — as a form of teacher behaviour, or as a form of student learning. For example, in the United Kingdom's national curriculum the descriptions at the beginning of 1990 were written in the form of what students should learn (Lavonen, 2011).

The terminology used in the national-level science curricula is diverse. For example, the concepts learning outcomes, aims, goals and objectives can have different meanings depending on the specific context. The concepts are sensitive and used in close relation to students' assessment. Although all of these terms have the same general meaning, they are used in different educational contexts. Learning outcomes are concerned with learners' achievements rather than teachers' overall intentions (Adam, 2004). These outcomes are statements that demonstrate a learner's knowledge and understanding after a period of study, the successful completion of a unit, course or programme in terms of the particular knowledge (cognitive), or practical skills and behaviour (affective) that a learner is expected to exhibit after a learning process according to the United Nations Educational, Scientific and Cultural Organization (UNESCO) definition. Goals indicate general intentions and are

not easily validated. Aims indicate the general content, direction and intentions behind the module from the teachers' viewpoint (Moon, 2002) and break down goals into measurable behaviours. Objectives on the other hand are stated in narrower, more precise, concrete and measurable terms. They support the learning outcomes in that each is a small step in arriving at what learners are supposed to know, or be able to do. Well-written objectives consist of verbs (action words), observable and measurable behaviours and specific levels of thinking. For example, they can be used to draw conclusions about observations and measurements and recognise the causal relationships associated with the properties of natural phenomena and objects (Finnish science curriculum, Physics and Chemistry grades 5–6). Concepts, learning outcomes, goals, aims and objectives are used in the national-level curricula in both Finland and Thailand. However, there are variations in the use of these terms between the Finnish and Thai curricula, and this can be a limitation for curricula analysis. For the science curricula analysis in this research report, only the primary level was emphasised.

Moreover, in this section, information on the science curricula of various countries and regions is introduced, including Europe, the United States, Australia and Asia so that we can see the general trends and basic aspects of science curricula in the different continents.

In the United States, the science curriculum has been reformed three times since the 1950s. Several frameworks have been developed at a national level, and they have all influenced state-level and local reforms. The well-known reforms are *Science for All Americans*, *Benchmarks for Scientific Literacy*, and the *National Science Education Standards Project*. In this movement, students are encouraged to do the following (AAAS, 2005):

- Become familiar with the natural world and recognise its diversity and its unity.
- Understand concepts and principles of science.
- Become aware of the ways in which science, mathematics and technology rely on one another.
- Know that science, mathematics and technology are human enterprises.
- Identify their own strengths and limitations.
- Develop the capacity for scientific thinking.
- Use scientific knowledge and ways of thinking for personal and social purposes.

Science for all Americans benchmarks different models of science curricula and defines specific goals and objectives for science education. The *National Science Education Standards* represent a framework for providing qualitative criteria and judge science programmes in terms of content, teach-

ing and assessment at K–4, 5–8 and 9–12 levels including learning goals, instructional methods, design features and assessment characteristics. The standards underline the following:

- The importance that all students understand science in terms of all natural sciences and their interrelationships and connections with technology, science- and technology-related social challenges (STS), and the history and nature of science.
- The preparation and continuing professional development of teachers and resources needed for teachers to reach their learning goals.
- A long-term vision for science education.
- The criteria for judging models, benchmarks, frameworks, curricula and learning experiences developed under the guidelines of ongoing national projects, or under state frameworks, or local district, school or teacher-designed initiatives.
- The criteria for judging teaching, the provision of opportunities to learn valued science (including such resources as instructional materials, educational technologies and assessment methods) and science education programmes at all levels. Science education for K–12 purposes to emphasise scientific and technological literacy.

In this century, science education in the United States focuses on the practices of science that lead to a greater understanding of the growing body of scientific knowledge that is required of citizens in an ever-changing world. Laboratory science is a main approach to science education provision as it provides opportunities for students to develop scientific arguments and explanations based on observations made during investigations. The expected learning outcome of lab-based science is that K–12 students should experience interactions with simulations and authentic data, access to large databases, physical manipulation of authentic substances or systems, remote access to scientific instruments and observations (NJ Department of Education, n.d.).

In several European countries, science is taught as an integrated subject in primary and lower secondary education. Most countries start to separate science into biology, chemistry and physics in upper secondary education. Such countries still emphasise the connections between different science subjects by supporting teachers to apply cross-curricular approaches whenever they can. To increase the motivation and interest of students in science learning, the students' real-life experiences and discussions of aspects of science in terms of society and philosophy are important issues. Furthermore, other issues of science education in Europe are context-based and related to contemporary societal issues, environmental concerns, scientific methods and scientific achievement, and scientific knowledge that students are recom-

mended to grasp from science education. For example, environmental concerns and the application of scientific achievements to everyday life are topics of discussion in science lessons in many European countries. At the primary level, the recommended activities for science learning include collaborative, hands-on work and project work. Occasionally, debates on science and societal issues are one of the teaching methods used usually in upper secondary schools. Moreover, teaching methods such as participatory inquiry and hands-on activities are applied in science teaching from the primary level onwards (Education, Audiovisual and Culture Executive Agency, 2011; Osborne & Dillon 2008).

Over the last six years, there have been general curriculum reforms at various levels of education in more than half of the European countries. Those reforms directly affect science curricula, and the main purpose of the reforms is the European desire for ultimate access to the European key competence approach. For example, a new national curriculum for science called Twenty First Century Science was recently introduced to students aged 14–16 in England and Wales (Burden, 2007). At the heart of Twenty First Century Science is a core course followed by all students, known as GCSE Science, which is an academic qualification awarded in a specified subject, generally taken in a number of subjects by students aged 14–16 in secondary education in England, Wales and Northern Ireland. The main aims of Twenty First Century Science are to promote an understanding of the essential points of media reports on science-based issues, the ability to reflect critically on the information in, or crucially omitted from, such reports, and taking part confidently in discussions with others about issues involving science.

The Australian science curriculum has developed as a consequence of widespread concern with the quality of science teaching and learning in Australia as well as students' engagement in learning science. The new curriculum calls for reform-minded scientists and educators to change the way science in schools supports teaching practices that engage students in quality learning (Tytler & Hobbs, 2011). The national curriculum board in Australia (2009) provides information on the aims and structure of the country's science curriculum as follows:

The Australian Science Curriculum emphasises science as a human endeavour that students should learn to appreciate and apply to daily life. The curriculum is focused on three interrelated strands: First, science understanding comprises biological, chemical, earth and space and physical sciences. Second, science as a human endeavour consists of the nature and development of science and the use and influence of science. Third, science inquiry

skills consist of five sub-strands: questioning and predicting, planning and conducting, processing and analysing data and information and evaluating and communicating. The science curriculum in Australia is described (Australian Curriculum, Assessment and Reporting Authority, 2010). From the fundamental year to year 2, the curriculum emphasises self-awareness and the local world. Students learn through exploratory, purposeful play of their investigations. The curriculum for years 3–6 focuses on recognising questions that can be investigated scientifically and then investigating them. Students learn, by observation and investigation, the content related to the complex natural or built world, the world as composed of systems and how components, or parts, within systems relate to living structures, living things, earth, changes of solids to liquids, features of light and electrical circuits.

Science education in Asian countries also plays a vital role in all other countries and societies in the 21st century. Roy-Singh (1991) researched the Asian-Pacific perspective on education in the 21st century. He suggested that science and technology can support societies when they aspire to become more technologically advanced in the next century. Science education, in one form or another, has a recognised place in school education in Asian-Pacific countries. According to Roy-Singh (1991), science education in Asia focuses mainly on three aspects: first, it should be designed to prepare students for science studies and support the development of expertise; second, science education programmes should prematurely split off the science disciplines into specialised groups; and third, the links of science and technology in science education programmes should be substantial and strong.

To understand the science curricula in several Asian countries, I provide general information on science curricula in China, Japan and Taiwan below. In the Chinese science curriculum, the main problems are as follows (Poisson, 2000):

- The curriculum is too subject- and knowledge-centred.
- There is an emphasis on science, rather than technology.
- The recitation of science prevails over science as inquiry.
- Teachers fail to instil scientific attitudes, values, processing skills and higher-order thinking skills in their students.

The aim of the Chinese science curriculum is to make science and technology powerful instruments to improve the quality of life, overcome superstitions and enable citizens to actively participate in decision-making pertaining to social and scientific affairs. The new Chinese science curriculum supports students in six domains: knowledge, science laboratories and operational skills, scientific skills, application, creative and attitude domains. Science and technology education should be enhanced in all primary and secondary

schools in China (International Bureau of Education, the Chinese National Commission for UNESCO, 2001).

In Japan, it is important for students to learn science so they can eventually be trained in its practical aspects through laboratory and other experiments. Students learn to develop their abilities of observation, interpretation and knowledge application. Learning relates to everyday life and applied technology; the aim is to develop the basic capabilities and creative skills required for rapid societal environment change (Goto, 2000). In primary education, students in grades 1–2 are introduced to science through “Life environment studies”. Students use experiments and observations to gain insights into natural phenomena. From grade 3 onwards, students start learning science as a discipline. Students are expected to take three units, “Living Things and Their Environment”, “Matter and Energy”, and “The Earth and the Universe” during each of the four years (grades 3–6) representing biology, physics, chemistry and earth science. The general goals of the primary school science curriculum are (Mayer, n.d.) to develop the ability to problem solve and a rich sensitivity to, and love for, nature. In addition, students should gain an understanding of natural things and phenomena, achieved by familiarizing pupils with nature and through observation and experiments, thereby fostering a scientific view and thinking.

Taiwan has reformed its curriculum every 10 years since 1993-4. Due to rapid societal changes, globalisation, the promotion of democratic literacy and an eagerness for education reform in Taiwan, the government organised a mission-oriented project group — the Curriculum Development Special Programme Committee — which focuses on the nine-year elementary and junior high school education span (Chiu, 2007, p. 304). The aims are as follows:

- To emphasise the coherence and integration of the grades 1–9 curriculum.
- To use learning areas and integrative teaching as rules.
- To construct the core framework with core competencies.
- To plan English teaching in elementary schools.
- To provide flexible teaching periods for teachers to make good use of school-based curriculum.

In Taiwan, scientific and technological literacy is one of the main goals of elementary and secondary school education. Taiwan changed the emphasis from teaching subject knowledge in separate domains to a curriculum that aims to integrate major scientific concepts, basic abilities and technology for all students. Chang (2005) studied the new Science and Life Technology Curriculum Standards (SaLTS) for grades 1–9 and stated that SaLTS is a systematic way of developing students’ understanding and appreciation of individual-society-nature interactions represented in the field of science and

technology. The aim of this is to integrate a broad range of subject matter, such as biology, chemistry, earth sciences, physics and technology. The purpose of new science and technology curriculum standards is to guide teachers in developing students' understanding and appreciation of three interactions: the individual and himself/herself, the individual and society and the individual and nature. The general objectives are defined in SaLTS as follows:

- To stimulate students' interest in and enthusiasm for science and to help students develop autonomous learning habits.
- To help students acquire fundamental knowledge and inquiry methods in science and life technology and apply that knowledge and those methods to their daily lives.
- To increase students' positive perceptions in cherishing the environment, treasuring resources and respecting life.
- To help students develop skills that are useful in cooperating and communicating with others.
- To develop students' independent-thinking and problem-solving abilities and to stimulate their creativity and potential.
- To promote students' awareness of the interactions between humans and technology.
- To motivate students to learn science and help them to apply their scientific knowledge in their everyday lives, the science content was reduced from SaLTS.

There are some similarities among all science curricula in the countries reviewed above, such as their (a) emphasis on science inquiry and the learning of procedural and epistemic knowledge; (b) emphasis on core scientific concepts, scientific skills and scientific methods through appropriate learning approaches; (c) application of scientific knowledge to everyday life situations, contemporary societal issues and environmental concerns. Therefore, the probable trend of science education at the primary level in the 21st century across nations would concern those three previous issues. Nevertheless, some countries emphasise different issues in the curriculum than others; for instance, in European countries, the science curricula also focus on increasing the motivation and interest of students in science learning, using a context-based approach in teaching science and implementing a new paradigm, social-technology-society (STS) in science education. In Asian countries, the science curricula mostly emphasise the importance of scientific methods and the application of science and technology as in the United States. The Australian science curriculum takes the PISA Scientific Literacy Framework into consideration in its provision of science education (Aubusson, 2011).

The PISA Scientific Literacy Framework plays an important role in student scientific literacy assessment at the international level. The assessment

has had an impact on science education reformation in several countries. When national-level curricula are compared to the PISA framework, interesting similarities and differences can be observed. For example, the Australian science curriculum regards the PISA framework in terms of the competencies dimension: *identify and investigate scientific questions, draw evidence-based conclusions and explanations about phenomena* to teach students. In several European curricula, motivation and interest *as the attitudinal dimension* are emphasised in the curriculum to arouse students' interest in science learning and to encourage them to act responsibly toward natural resources and their environments. The knowledge dimension could be met in the science curricula of all countries either as integrated or separate fields such as physics, chemistry, biological science and earth and space science. Finally, the contexts dimension, especially everyday contexts, is introduced in all science curricula.

The information on science curricula demonstrated above illustrates the current state of science education and may also predict the trend for many countries in the future. This could be the foundation for further science education development.

2.1.2 Textbooks

The science textbook has been, and still is, an important tool in science education. The textbooks operationalise the curriculum. Typically, a textbook is written by a couple of experts and presents the authors' views on and interpretations of the curriculum. Some textbooks have been created through partnerships or through the activity of a group. In this section, the review of textbook research is divided into four main sub-topics as follows:

- The role of textbooks in general.
- Elements in science textbooks.
- Knowledge construction through reading a textbook.
- Supporting teachers' teaching through textbook use.

I will review the studies on textbooks in four sub-sections because of the broad topics covered when focusing on textbooks.

2.1.2.1 Role of textbooks in general

Textbooks are mediators in an instructional process and regarded as a source of information for students (Abimbola & Baba, 1996). The interplay between textbooks and teachers and students reflects the way textbooks are used for different purposes. For example, for teachers, the textbook itself is a source

of subject matter knowledge and a guideline for lesson preparation that will transmit the content to students through their pedagogy. Linked to this, Malcolm and Alant (2004, p. 72) suggested the following: “In schools where teachers often have limited content knowledge and planning skills, and where students need to do considerable work by themselves, textbooks serve as sources of science knowledge, curriculum planning and teaching ideas for teachers and students”. Accordingly, Korkeamäki and Dreher (2011) asserted that because a teacher’s workload is heavy, teachers tend to use materials that are easily accessible to them. Therefore, teachers read textbooks and teachers’ guidelines in order to follow the principles and content of the core curriculum. For students, textbooks are connected to their learning process as they help them construct new knowledge, or connect to their prior knowledge, to attain the objectives of that lesson in the form of content or subject matter. Gerard (2003, p. 10, as cited in Pop-Păcurar & Ciascai, 2010, p. 1) defined the textbook as follows: “The textbook has the following characteristics: performs different functions associated with learning, serves to achieving some objectives, suggests different types of activities, likely to support the learning process”.

2.1.2.2 Elements in science textbooks

Science textbooks contain blocks of text, pictures, diagrams, charts, models and numbers. All of these are used to communicate ideas and concepts as representations. Roth and McGinn (1998) proposed the idea that “it is therefore not surprising that instructional materials contain, in addition to written text, many graphics such as maps, charts, diagrams, tables, and graphs” (p. 35).

Much research has been conducted on the representation concepts used in several fields including mathematics, physics and biology. The representations in the textbook have been categorised in many ways. For example, Carolan, Prain and Bruce (2008) suggested that diverse representations used in teaching and learning science can be divided into two groups: 3D and 2D representations. One of representations can be further categorised as specific to the domain of science (such as 3D models, tables, graphs, diagrams, science journals, multimodal reports, and appropriate vocabulary and measurement for specific topics) and generic representations used in the community and classroom. Accordingly, Pellathy (2009) classified nine types of representation: mathematical, graphical, pictorial, analogical, physical demonstration, free body force diagram, extended free body diagram, energy bar chart and simulation representation. Moreover, Slough et al. (2010) quantified the type and quality of the graphical representations and how they interacted with

the textual material in middle school science texts. They employed a researcher-developed instrument called the Graphical Analysis Protocol (GAP) as a tool for graphics coding. The results of Slough's study illustrated the importance of graphical representation in science textbooks because teachers in American middle school tend to rely heavily on texts that have become increasingly visual. There is little information available on the graphical demands of general middle grades' science texts.

Regarding textual information in textbooks, several studies have focused on text-based learning and engagement. For example, a situational interest or positive attitude to learning is the consequence of certain text characteristics or the context where the text has been presented (Hidi & Baird, 1986; Krapp, 2002). This interest or attitude could affect text-based learning. Moreover, Haiduc and Liliana (2011) investigated which metacognitive strategies are used by students in reading texts in science textbooks. They reviewed the research on the importance of text-based learning and reading comprehension and summarised that comprehension is a consequence of understanding the meaning of written words, sentences and texts. Comprehension is, moreover, influenced by the interaction of various factors, such as the content of the text, the reader's goals and prior knowledge and cognitive and metacognitive processes. Consequently, learning from a textbook involves comprehension at two essential levels: text-based and situation levels. The situational level, as previously mentioned, can refer to how the context in which the textual or pictorial information is presented, or the topic's relevance is demonstrated, could influence students' cognitive development. Therefore, context-based approaches have also had an influence on textbooks (Bennett, Hogarth & Lubben, 2003).

2.1.2.3 Knowledge construction through reading a textbook

Textbooks are composed of text, figures, graphs, diagrams, and forms of textual and pictorial information as mediatory tools for conveying their content. Science textbooks include many scientific concepts, which students encounter when they are reading the textbooks. Therefore, textual and pictorial information should help students to recognise their existing knowledge and support the connection of new concepts to previous concepts or cumulative learning.

Learning is more effective if the information is offered in situations familiar to students. Consequently, a science textbook has an important role in offering credible textual and pictorial information. Students are able to learn through processing this available information. Such ideas supporting con-

structivism are well-documented by research on the comprehension of written text and conclude that reading is a process of active construction of meaning (e.g. Bransford, 1979; Spiro, 1980). Furthermore, Macdonald and Pálsdóttir (2008) analysed the science ‘story’, which means all representations in books and not only the contents and concepts presented, but also the rhetoric (or story) being told to students being taught in middle schools in Iceland. The results reflect what children think and learn: what kinds of tools teachers use when teaching science, and then what level and type of support the teachers and children require.

2.1.2.4 Supporting teachers’ teaching by textbook use

When a teacher acts as a mediator of the information available in a textbook, s/he also employs the representations of the information in the textbook and other didactical principles in teaching. When a teacher uses a textbook, it indirectly changes his or her knowledge and beliefs about how children learn and which teaching strategies are most effective (Singer & Tuomi, 2003). Similarly, textbooks are considered as “pedagogical vehicles” for the perpetuation of “normal science” (Kuhn, 1970, as cited in Niaz, 2010, p. 891). In addition, Mohammad and Kumari (2007) analysed teachers’ experiences and practices related to the use of science textbooks in public schools in rural Pakistan. They found that the teachers’ limited use of textbooks reflected their lack of appreciation and acknowledgement of the textbooks as a useful resource. There were also problems related to the quality of the content provided in the textbooks. However, the teachers were not able to clarify the quality of content provided in the textbooks on their own. Therefore, Muhammed and Kumari emphasised the responsibility of the textbook authors to ensure the clarity of the language, the provision of adequate information and the avoidance of any misprinting errors. In addition, authors and editors should also ensure that textbooks provide adequate methodological guidance and input for teachers. In contrast to the research of Muhammed and Kumari, when teachers have limited knowledge of the subject matter, textbooks play a role as an important source of information during instruction, increasing their confidence in terms of content knowledge. Windschitl (2004, p. 5) suggested that “content knowledge has perhaps the greatest documentation as to its role in science teaching. Teachers with limited subject matter preparation tend to emphasise memorisation of isolated facts and algorithms; they rely on textbooks without using students’ understandings as a guide to planning lessons”.

Based on the research on textbooks described above, I will summarise the literature review by outlining the essential properties of a science textbook. A

science textbook should (a) be written in accordance with national level curricula; (b) transform scientific knowledge to a form that students are able to learn; (c) allow the use of different teaching methods and learning tools such as learning technology; (d) support students' learning, for example, the learning of reasoning skills, knowledge about science and knowledge of science, including factual knowledge, conceptual knowledge and procedural knowledge; (e) support the development of a positive attitude to science through demonstrating the relevance of science; (f) provide different representations of knowledge; (g) increase teachers' self-confidence when they lack content knowledge.

2.1.3 Teachers' knowledge

In this sub-section, several studies on PCK and GPK are introduced to describe the previous, current and future situation regarding PCK and GPK research. According to Gess-Newsome (1999), subject matter knowledge, PK and PCK form the knowledge base needed in teaching. In the same way, Williams, President of ASCD (2003, as cited in Krause-Phelan et al., 2011) stated, "We must give more attention to the interplay between the science of teaching—pedagogy—and the art of teaching...A teacher must be anchored in pedagogy and blend imagination, creativity and inspiration into the teaching learning process to ignite a passion for learning in student" (p. 298).

Teaching and learning are the main processes in the education system. The more teachers are involved in the processes of conducting and improving education, the more important it is that the role of education is discussed in society (Joyce, Calhoun & Hopkins, 2002). For this reason, teachers are an important factor in influencing students' learning process and helping them reach their educational goals. In fact, Brandsford, Brown and Cocking (2000) suggested that teachers are the key to enhancing learning in schools.

In recent years, teachers' knowledge has been widely discussed from several viewpoints of teaching and educational research including teachers' professional development, identity, self-evaluation and their teaching development. Therefore, in this research report, two main types of teachers' knowledge — PCK and GPK — are emphasised according to the aims of the research report.

2.1.3.1 Pedagogical Content Knowledge (PCK)

In my literature review of PCK, I classified the relevant research according to three broad lines: Group 1 [Gess-Newsome (1999); Grossman (1990); Coch-

ran et al. (1993); Park and Oliver (2008); Nilsson, 2008] have clarified the construct of PCK; Group 2 [Jones and Moreland (2004); Johnston and Ahtee (2006); Loughran, Mulhull and Berry (2008); Goodnough and Hung (2009); Anderson and Clark (2012)] aimed to study or measure the PCK construct; and Group 3 [Musikul (2007); Nilsson (2008); Kind (2009); Krzywacki's (2009); Kanter and Konstantopoulos (2010); Nilsson and Loughran (2012)] aimed to develop or improve teachers' characteristics that are consequences of the PCK construct.

First, Group 1 begins with an introduction of the primary idea of the PCK concept as presented by Shulman (1986). Shulman asserted that PCK represents "the blending of content and pedagogy into an understanding how particular topics, problems or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8, as cited in Gess-Newsome & Lederman, 1999, p. 4). Moreover, Grossman (1990) also renewed the concept by defining four central components of PCK: (a) knowledge and beliefs about the purposes of teaching a subject; (b) knowledge of students' understanding, conceptions and misconceptions of particular topics in a subject matter; (c) knowledge of curriculum and curriculum materials; (d) knowledge of instructional strategies and representations for teaching particular topics. Then, Park and Oliver (2008) added the last component, knowledge about the assessment of student understanding, to create the five constituent components of PCK. In addition, to further emphasise PCK in teaching and learning, Cochran et al. (1993, p. 1) stated that "PCK is the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students". Thus, PCK is largely accepted as a dynamic form of knowledge that is constantly expanding and being transformed based on other forms of teachers' knowledge through their experiences of planning, conducting and reflecting on (science) teaching and learning (Nilsson, 2008).

Secondly, the literature review of Group 2 introduced some general research on PCK focusing on teachers in science education. Much research has focused on science teaching both at primary and secondary levels. Notably, even though research on PCK has been prevalent, the research methodology has varied, as described below.

Jones and Moreland (2004) described the frameworks and cognitive tools that have been developed to enhance PCK in primary school teachers of technology education. Using case studies, their research focused on PCK from the point of view of teachers and their need to build a knowledge base for teaching about technology. Their findings showed that teachers increased their PCK on their own. Those teachers showed greater confidence in demon-

strating the formative interactions and placed more emphasis on assisting students to move on.

Johnston and Ahtee (2006) explored and compared primary student teachers' attitudes, subject knowledge and PCK in physics in two institutions in England and Finland. The findings revealed that the student-teachers in both countries required more education on the abstract concepts related to physics. However, some student-teachers may learn to plan and implement instructional strategies so that they can eventually attain a scientific understanding of basic physics concepts.

Loughran, Mulhull and Berry (2008) explored the outcomes of PCK using a pre-service science teacher programme; student-teachers' thinking about their teaching and about their development as science teachers was shaped using a Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) conceptualisation. According to the results, the student-teacher participants should see PCK through a CoRes and PaP-eRs conceptualisation as a way of looking at how they might develop their own professional knowledge of practice.

Goodnough and Hung (2009) examined how five elementary teachers engaged and developed their PCK through problem-based learning (PBL) activities. They used a variety of quality methods, i.e. videotaped teaching sessions, audio-taped sessions, electric journal entries. The study highlighted that PCK is a critical element in effective teaching. Classroom practice is a reflection of not only a teacher's content knowledge, but also of his or her fundamental teaching.

In their case study, Anderson and Clark (2012) analysed the practice of New Zealand elementary teachers using a framework developed based on Shulman's conceptualisation of teacher knowledge. They took CK and PCK aspects into account in their study to examine teachers' instructional practices and found that they applied practical strategies in teaching syntactic aspects of science.

Finally, Group 3 includes studies based on the consequences of the PCK construct. The consequences can be developed or applied to some characteristics of teachers in terms of PCK. Some research on PCK in European countries and Thailand is reviewed below.

In Thailand, there has been little research in the area of PCK in science education. Musikul (2007) researched the nature of professional development in the context of Thailand in a holistic way to gain an understanding about knowledge and orientation as well as the implementation of professional development. The findings and implications of the study for professional

development (PD) and professional developers in Thailand are outlined in the paragraph below:

The professional developers deviated from the reformed Thai Science Education Standards. Professional developers also had limited PCK for PD, and their knowledge and orientations influenced their decisions in selecting PD activities and teaching approaches. Musikul's review of PCK in elementary science teaching revealed that the research focused on professional development in science teaching because it can support teachers to change from traditional teaching approaches called lecture-based strategies to more constructive approaches by encouraging students to think and construct through hands-on activities. Therefore, teachers' understanding of the importance of PCK is one of the main factors in ensuring that students learn effectively.

Nilsson (2008) found that the process student-teachers undergo in learning how to teach science in primary schools is based on their teacher education programme. Nilsson's thesis was divided into four papers in which the key question was how student teachers learnt about illustrated teaching and understood the critical aspects that are experienced within their teaching and learning practices. In her first paper, Nilsson explored how different elements of PCK may be recognised and how they enhanced the importance of the need for a conceptualisation from an abstract to a concrete construct. She found that the student-teachers struggled to teach with their specific need and from this sometimes transformed into PCK. Therefore, PCK is one important aspect of teachers' knowledge, and the study of the learning process in teaching student-teachers needs to include PCK. Fortunately, PCK can be developed via classroom experiences.

Kind (2009) concluded that PCK use was beneficial in science teacher education courses. For example, novice and experienced teachers who have knowledge of PCK may help themselves to develop and improve their practice. To reach these aims, Kind proposed that (a) we should agree to adopt a transformative model of PCK for initial training, or situations in which experienced teachers are learning to teach new subjects; (b) teacher education courses should make explicit what PCK is, for example, by introducing Content Representations (CoRes) as a way of describing current practice, and/or using completed CoRes as exemplar material; (c) attention must be given to the emotional side of becoming and being a teacher.

Similarly, Krzywacki's (2009) research examined three aspects of teachers' identity formation in mathematics teacher education—the cognitive and affective aspects, the image of an ideal teacher directing the developmental process, and as an on-going process. The teachers' PCK was examined as one aspect included in the cognitive aspects of this research.

Kanter and Konstantopoulos (2010) aimed to support the development of teachers' CK and PCK through a professional development project. Within the project, teachers taught project-based science (PBS) lessons in the field of science content knowledge learned during the professional development project. Teachers used the Project-based Science PBS curriculum in their classrooms and had the same amount and type of support from the professional development programme in learning to use the PBS curriculum as intended. The teachers' reflective essays in the context of planning for, or reflecting on, their own practice revealed PCK that was different from the PCK seen when actually engaging in teaching practice. The correlation between the levels of post-CK and post-PCK that teachers attained and the impact of the PBS curriculum on students were analysed. The analysis showed that CK and PCK support teachers' social constructivist pedagogical practices.

Nilsson and Loughran (2012) examined how a group of pre-service elementary science student teachers came to understand the development of their PCK over the course of one semester's study on a science methods course. The participants were student-teachers on a three-and-a-half-year pre-service elementary teacher education programme. Based on the measurements and analysis, the student-teachers gained PCK and were able to learn new ways of planning and evaluating their work.

All of the research examples described above reveal that the concept of PCK has been used to conduct research in different areas of science education and for different grade levels, including primary school teachers. Moreover, the concept could be used to monitor teachers' progress during professional development projects. Most European countries have realised the importance of teachers' PCK as one aspect of teachers' knowledge. There are also examples from Thailand. However, the challenge in using the PCK concept is the differences in the meanings of the concept based on its broad use in various contexts.

My research on PCK belongs to the second broad line of research. Although my study of teachers' PCK and GPK (the 3rd study) does not investigate them in the context of classroom teaching, it does at least demonstrate some expressions or sentiments of science teachers who are the principal individuals providing classroom instruction. A teacher's level of thinking is very important for instruction, for instance, regarding how to transform the content in a lesson to make it easy for students to understand, what material should be selected for the lesson, and so on. A teacher's thoughts lead him/her to have *pedagogical reasoning*, a vital stage of PCK possession.

2.1.3.2 General Pedagogical Knowledge (GPK)

As previously mentioned, GPK is a central component of teacher knowledge (König & Blömeke, 2012, p. 341). Based on Shulman's original conceptualisation of teacher knowledge, this knowledge is comprised of three main aspects: PCK, CK and GPK. Many scholars have defined and categorised the characteristics of GPK from diverse viewpoints. First, GPK is the knowledge of how to moderate discussions, design group work, organise materials for student use and utilise texts and media. It involves "broad principles and strategies of classroom management and organization that appear to transcend subject matter" (Shulman, 1987, p. 8). Second, Grossman and Richert (1988, p. 54) stated that GPK "includes knowledge of theories of learning and general principles of instruction, an understanding of the various philosophies of education, general knowledge about learners, and knowledge of the principles and techniques of classroom management". Finally, Morine-Deshimer and Kent's (1999) concept of GPK focuses on three main categories: the instructional model (teaching method), classroom management and classroom communication. These categories were included in my research report as part of a main conceptual framework.

General pedagogical knowledge has always been investigated as a set of teacher knowledge. It is quite difficult to find research studies specifically on GPK, and as Wilson and Berne (1999) stated, empirical studies are lacking in information on the GPK of future teachers. However, two studies on GPK have been performed by König and his colleagues. The first study by König et al. (2011) attempted to measure GPK as an element of the professional knowledge of future middle school teachers in the United States. This study aimed to be an international comparison with future middle school teachers in two culturally different countries, namely, Germany and Taiwan, utilising the Teacher Education and Development Study in Mathematics (TEDS-M) GPK survey as a research instrument. The TEDS-M test measuring GPK consists of four dimensions of GPK according to the QAIT model introduced by Slavin (1994): *structure, motivation/classroom management, adaptivity and assessment*. Furthermore, the survey covers the dimensions of cognitive processes — *recall, understand/analyse and generate* — following Anderson and Krathwohl's (2001) taxonomy as another model for surveying. Findings from the TEDS-M survey revealed that future middle school teachers in the United States were significantly outperformed by future teachers in Germany and Taiwan with regard to their overall GPK test scores. The United States future middle school teachers showed a relative strength in one of the cognitive sub-dimensions, generating strategies for performing in the classroom,

indicating that in particular they had acquired procedural GPK during their teacher training.

The next study by König and Rothland (2012) examined the effects of pre-service teachers' motivations for their teaching in their GPK by using a sub-sample of 130 pre-service teachers in Germany whose GPK was tested twice. The researchers used 52 items of the German translation of the FIT-Choice scale documented by Watt et al. as a research instrument to measure the teachers' motivations. Overall, the items covered four factors: motivational factors, factors concerning future teachers' perceptions, social dissuasion factors and satisfaction with their career choice. The findings concentrated only on GPK and indicated that intrinsic motivation was positively correlated and extrinsic motivation was negatively correlated with GPK on the first occasion of measurement. The correlations between the FIT-Choice scale and GPK, motivations and knowledge were not very closely related.

Regarding the GPK theory proposed by Morine-Deshimer and Kent (1999) that I used for my research, prior researchers have presented three aspects of Morine-Deshimer and Kent's GPK concept: classroom management, teaching method and classroom communication. For example, Baker, Lang and Lawson (2002) investigated teachers encountering classroom management problems during inquiry teaching. They described some of these problems and suggested some ways for avoiding them or reducing their severity. It is extremely important that a teacher develops techniques that allow the effective implementation of inquiry-based activities. The conclusion part of the study by Baker, Lang and Lawson (2002) indicates that inquiry classes present experienced teachers with a unique challenge that often requires them to modify activities to meet individual student needs. Hands-on inquiry activities have proven to be effective in assisting students to understand content and in acquiring process skills. In addition, classrooms are more successful when teachers are able to differentiate instruction.

She and Fisher (2002) investigated the assessment of students' and teachers' perceptions of science teachers' interpersonal communication behaviours in their classroom learning environments in Taiwan by employing The Teacher Communication Behaviour Questionnaire (TCBQ). The results indicated that girls perceived their teachers as more understanding and friendly than did boys, and teachers in biological science classrooms exhibited more favourable behaviour toward their students than did those in physical science classrooms. Positive relationships were found between students' perceptions of their teachers' communication behaviours and their attitudes toward science. Students' cognitive achievement scores were higher when students

perceived their teacher as using more challenging questions, as giving more nonverbal support and as being more understanding and friendly.

Southerland and Gess-Newsome (1999) detailed pre-service teachers' understandings of teaching, learning and knowledge and described how these pedagogical understandings influenced their approach to inclusive science teaching. Southerland and Gess-Newsome (1999) provided implications for science teacher education by first focusing on a fixed and defined body of scientific knowledge that is accessible to all students in classrooms, within the confines of the students' fixed abilities. Second, pre-service science teachers must become aware of their own racial and cultural roots to be prepared to understand the cultures of the students in their classrooms. Finally, the image of learners with fixed abilities may be best addressed through making this image explicit when it emerges in class discussions and class work.

Furthermore, Tosun (2000) examined the beliefs of pre-service elementary school teachers toward science and science teaching by examining prior experiences in science courses, as well as achievement in such courses. His conclusion suggested that teachers' instructional approach will be effective and more meaningful when they believe in themselves, have a sense of self-efficacy and are able to use a variety of instructional strategies, including team teaching and differentiated instruction.

Kamen (1996) studied the implementation of authentic assessment strategies in one female elementary school teacher's science classes using a phenomenological approach. According to the findings, when working with teachers it is important for students to help them find authentic ways to share and expand their views of learning and teaching, just as teachers must find authentic ways to help children expand and share what they know. This was a powerful force in these children's development as science students.

In conclusion, GPK is one of the teacher knowledge domains that refers to how teachers' activities and instructional methods in the classroom affect students' learning. Therefore, every factor in the classroom is organised for meaningful teaching, e.g. time, learning materials, classroom equipments, classroom environment and teaching method. Teachers need to ensure all of these effective factors and seek an appropriate way to utilise them in a valuable manner for teaching and learning. Moreover, in general, teachers themselves have GPK intuitively. This means that teachers themselves need to have basic knowledge about classroom decoration, selection of learning equipment, classroom environment preparation and teaching methods.

3 Comparative research methodology

An overview of the research methodology is presented in this chapter. Differences in students' success on the PISA Scientific Literacy Assessment and in the science educational contexts in Finland and Thailand were the main reasons for the comparative study. This methodology will be used for investigating three main comparative studies in this research to present the existence of their results.

3.1 Main research methodology

Comparative research is a research methodology conducted in social science. It has been defined as “a method of analysis that focuses on several objects of study in order to identify similarities and differences” (Goedegeburre & van Vught, 1996, p. 378). Hantrais and Mangen (1996) proposed the idea that the comparative research methodology can provide interesting insights and a deeper understanding of issues that are of central concern in different countries, lead to new, refined perspectives on a subject and also identify gaps in knowledge that prevent effective cross-national comparisons. Consequently, this will suggest beneficial directions for future research to identify the similarities and differences of findings across nations. In this cross-cultural study, three sub-studies have been conducted. However, it is challenging to compare science education across two countries because there are many different factors in the cultural setting of each country, i.e. traditions, cultures, value systems, lifestyles, thought patterns, environments and languages.

Many scholars have defined the term comparative research based on two main groups: those emphasising diverse fields of study (social science and political science), and those focusing on a number of study cases. In *Group I*, emphasising fields of study, Lor (2011) noted that comparison is inherent in all sciences, including the social sciences, where comparative research has historically played a significant role in their development as scientific disciplines. Similar to Mills, van de Bunt and de Bruijn (2006) emphasised that comparative research can provide both quantitative and qualitative comparisons of social entities defined in the term. Social entities could refer to many fields, such as geographical, political or education policy fields in the form of cross-national or regional comparisons. In *Group II*, which focuses on a number of study cases, researchers compare the relative effects of variables across cases; they compare cases directly with one another, and they compare empirical cases with counterfactual cases. The comparative

method — or small-N comparison — constitutes a distinctive approach in understanding social phenomena (Ragin & Rubinson, 2009).

In this research, I mainly used the comparative approach by conducting a cross-national study of Finland and Thailand. In practice, science curricula were studied and a content analysis of textbooks was performed. Interviews were conducted with primary teachers to understand how they employ PCK and GPK when teaching students about electric circuits. According to Stake (2005), a case study is not a methodological choice, but a choice of what is to be studied. The primary goal of a case study is to gain an in-depth understanding of a particular case, which provides rich and detailed descriptions, for example concerning people's lives, experiences and circumstances (Monette, Sullivan & Dejong, 2008).

In order to evaluate the PCK and GPK of Finnish and Thai teachers, an instrumental case study approach was adopted. A case should be purposefully selected that is, for instance, information-rich, critical, revelatory, unique or extreme (Stake, 1995; Patton, 1990). If a case is purposefully selected, then there is an interest in generalising the findings. Not only the case selection, but also the context has to be realised for this approach. Miles and Huberman (1994) suggested that it should not only concern the case(s) (people as research participants), but also the situation and context to be examined. In order to research teachers' PCK and GPK, three primary school teachers from Finland and three from the capital city in Thailand were selected as the cases. The context was science instruction at grade 6 in Finnish and Thai schools, and sixth grade science textbooks were selected for the analysis of textbooks. The rationale is explained in detail in Chapter 5, Section 5.2 and the criteria for teacher selection are described in detail in Chapter 6, Section 6.3.1.

3.2 Research data management

In terms of data handling, the content analysis was one method of handling the data for the three sub-studies (as aforementioned in Chapter 1, Section 1.2.5). As Weber (1990) stated, content analysis refers to a method of transforming the symbolic content of a document, such as words or images, from a qualitative, unsystematic form into a quantitative, systematic form. Therefore, both textual and pictorial information in the national-level curricula and the textbooks was analysed according to identified categories and subcategories. Similar to the interview expressions of primary school teachers, the expressions were condensed and categorised. To identify the categories and subcategories for the data analysis, I first reviewed the

relevant literature and defined the categories and subcategories. Then, all of the content —the sentences, phrases and pictures shown in the curricula and textbooks — was analysed sentence by sentence, or phrase by phrase, along with the defined categories and subcategories. Consequently, the analysis can be characterised as deductive. For the interview data, I employed the ideas of deductive content analysis (Elo & Kyngäs, 2008).

In conclusion, the methodologies used in the sub-studies are summarised in Table 1. Research methodologies are described in detail for each separate sub-study.

Table 1. Research methodology used in each separate sub-study

Sub-study	Conducted approach	Analysis of data
Science curricula analysis	Comparative approach	Theory-driven content analysis of national-level science curricula
Science textbooks analysis	Comparative approach	Theory-driven content analysis of science textbooks
Interviews of primary teachers on PCK and GPK	Comparative approach	Theory-driven content analysis of expressions and
	Case study approach	Interviews

4 Comparative Study I: National science curricula analysis at primary school level

Teachers need clearer guidance on how to plan and develop teaching in line with educational goals. The curriculum should be a meaningful, relevant and a clear entirety that supports teachers work, and provides space for students and teachers to develop their own pedagogy. (Vitikka, Krokfors, & Hurmerinta, 2012, p. 89)

What is a curriculum? A curriculum is a document that guides the education processes on a national or local level (Kelly, 2009; van den Akker, 2003). In some countries, such as the UK, there is a centralised education system and, in other countries, such as Finland and Thailand, there is a decentralised education system, where a local curriculum is prepared based on the national-level curriculum. However, in both cases, the national-level curriculum is an important tool for the implementation of the national education policy. A curriculum is a tool for the renewal of science education. For example, *Science Education International* introduces several renewal programs where the role of the curriculum is important, such as a renewal of inquiry-based (Chabalengula & Mumba, 2012) or context-based (Valdmann, Holbrook, & Rannikmäe, 2012) science education.

Curriculum theorists argue that two types of curricula are guiding teaching and learning at school. The intended, official, virtual, overt or explicit curriculum is a ‘formal’ document that describes ‘official’ aims and contents or describes an intentional instructional agenda of a school. The hidden, implicit or covert curriculum is made up of the unwritten ‘messages’ that students receive from their school environment, informal codes of conduct, behaviours and attitudes that are learned through interactions with teachers, administrators and others in schools (Oliva, 1997).

4.1 Aim of the study

This sub-study aims to compare intended national-level curricula in two different countries to compare intentional instructional agendas. I will present the comparison of a high- and a low-performing country in the PISA scientific literacy assessment to see if there are differences in the aims the intended curriculum is emphasising in two differently performing countries. I chose the Finnish and Thai national-level intended primary science curriculum for the analysis. Finnish PISA scores have been extraordinary due to both the high scores and the low variation in performance (OECD, 2007; 2010). On the other hand, the PISA results of Thai students are among the

lowest in the world. The similarities between the Finnish curriculum and the PISA Scientific Literacy Framework have been one proposed explanation for Finnish students' success in PISA (Lavonen & Laaksonen, 2009).

Even though curriculum analysis will not offer information on the classroom practice level or hidden curriculum, it will clarify the guidelines that the teachers should follow and take into consideration in their teaching. Teachers need to know the curriculum guidelines when they decide on teaching methods, select content and learning materials and decide on ways in which to assess student achievement.

This study analyses similarities and differences between the national-level curricula in Finland and in Thailand to determine the core aims and contents. However, the research on the science curriculum is not straightforward because the education context and the terminology used in the curriculum documents vary between countries and researchers. For example, the use and definitions of the terms objective, aim, goal, ability, learning outcome and competence vary. 'Goals' is used typically to describe the overall purpose of a subject or of a course in a national-level curriculum. 'Aims' break down goals into measurable behaviours. Objectives are stated in narrower, precise, concrete and measurable terms. They are stated in terms of what the learner should know, or be able to do or should have attained by the end of a course or at the end of compulsory schooling; these attainments are called learning outcomes (Duggan & Gott, 1995).

The PISA 2006 Scientific Literacy Framework (OECD, 2006) was applied as a framework for the analysis. There were two reasons why I chose this framework. Firstly, the Finnish and Thai primary science curricula differ substantially and the PISA frame offers a neutral frame for the analysis. Secondly, my aim is to compare national-level curricula to an internationally agreed framework that is used to assess how well students have acquired the knowledge, skills and scientific literacy that are essential for their full participation in society or competence in all their future lifelong learning. These aims are fundamental national-level aims for education. Therefore, the research questions are:

1. What do Finnish and Thai science curriculum emphasise within the PISA scientific literacy framework?
2. What are the similarities and differences between Finnish and Thai science curriculum regarding the PISA scientific literacy framework?

To compare both science curricula, an overview of Finnish and Thai primary science education is introduced, as follows.

4.1.1 Science education in Finland

Finnish national policy emphasises broad literacy and, consequently, all school subjects have equal priority in the Finnish curriculum (Lavonen, 2008; Stål, 2012). The Finnish *National Core Curriculum for Basic Education* (FNBE, 1994; FNBE, 2004) describes the national aims and contents for physics, chemistry and biology education. In addition to conceptual knowledge, ‘science curriculum emphasises activities in which the students can identify, recognise or observe scientific issues, explain or interpret data or scientific phenomena, and draw conclusions based on the evidence’ (Lavonen & Laaksonen, 2009). Practical work and demonstrations, aiming at learning process skills, have long been accepted as an integral part of the teaching and learning of science subjects (Asunta, 1997).

Science covers six subjects: environmental and natural studies, biology, geography, physics, chemistry and health education in grades 5–9. In grades 1–4, there is an integrated subject of environmental and natural studies. There are 38 weeks in a school year and each lesson lasts for 45 minutes. The average number of science-instruction lessons per year on each level is as follows: grades 1–4, 64 lessons per year; grades 5–6, 71 lessons per year; thus a total of 400 lessons are allocated for science studies in grades 1–6 in Finnish compulsory schooling.

According to the Finnish core curriculum, the purpose of science teaching in general is to help students to: 1) perceive the nature of science; 2) learn new scientific concepts, principles and models; 3) develop skills in experimental work; 4) engage in cooperation; and 5) become stimulated to study physics and chemistry (*interest*) (NCCBE, 2004). Finnish aims are described as broad aims indicating what a teacher should teach during science lessons.

In grades 1–4, *Environmental and natural studies* is an integrated subject group comprising the fields of biology, chemistry, geography, physics and health education. This is a compulsory subject. The aim of the instruction is to teach students to know and understand nature and the built environment, themselves and other people, human diversity and health and disease. There are four content areas in environmental and natural studies: physics, chemistry, biology, and organisms and living environments. The latter covers issues on the basic features of living and non-living nature and the adaption of organisms. The source and production of food is also covered.

In grades 5–6, there are two science subjects: integrated biology and geography, and integrated physics and chemistry. Important topics of physics are, for example, energy and electricity, scales and structures; and important topics of chemistry are substances in the environment, the atmosphere, water, classification of substances and the recycling of products. Energy and elec-

tricity is an important area of physics. According to the core curriculum, the students should learn about the production of heat, light and motion with the aid of electricity; safety with electricity and various ways of producing electricity; and energy resources. Students should learn science process skills in physics and chemistry, such as:

- formulating questions;
- making observations and measurements;
- presenting and testing hypotheses;
- processing, classifying, presenting and interpreting observations and data;
- generating evidence-based conclusions;
- formulating simple models and using of these models for explaining phenomena;
- looking for information from different sources of information; and
- carrying out simple scientific experiments.

4.1.2 Science education in Thailand

Chandavimol (1990) described the Thai curriculum after reform at the end of the 1980s. In that reform, the process approach was emphasised. According to Yuenyong and Narjaikaew (2009), the next reform in 1999 focused on scientific literacy: 'Thai science education emphasizes the scientific knowledge, the nature of science, and the relationship between science technology and society' (p.335). The definition of scientific literacy in the Thai science education context focuses on citizens who are to be able to: (1) perceive questions and problems that could be verified through the scientific method, (2) identify evidence or data for inquiry, (3) give reasonable explanations related to empirical data or evidence, (4) communicate or explain issues related to science, and (5) understand scientific principles and concepts. The Institute for the Promotion of Teaching Science and Technology (IPST, 2002) emphasised that, although Thailand is not a member of the OECD, the country aims at a similar scientific literacy to that of OECD member states.

Science is a compulsory topic for Thai students in every grade from the primary level to the upper-secondary level. The time allocated to science instruction is 80 lessons per year at all primary levels. The duration of a lesson is 50 minutes. Altogether, there are 480 lessons allocated in grades 1–6 in Thai schools. There are eight content areas in the curriculum: 1) living things and processes of life, 2) life and the environment, 3) substances and properties of substances, 4) forces and motion, 5) energy, 6) the change process of the earth, 7) astronomy and space, and 8) the nature of science and technology (Ministry of Education, 2008).

Each content area or topic contains sub-topics and, under the sub-topics, there are standards of science as well. Students in different grades are taught the same main content and sub-topics but at the appropriate grade level. The standards of science dictate what subject matter the students should learn under each content area or sub-topic. Consequently, the aims are described in the form of learning outcomes. The descriptions of specified grade level learning outcomes could be interpreted as guidelines for teachers' instruction so that learners will learn the topics that have been outlined. For example, the general standard for the topic of *Living organism and family* is: 'Understanding basic units of living things; relationship between structures and functions of living things, which are interlinked; investigative process for seeking knowledge; ability to communicate acquired knowledge that could be applied to one's life and care for living things' (Ministry of Education, 2008).

In general, the purpose of science teaching in Thailand is described as follows: Science teaching should help the students 1) understand basic principles and theories of science; 2) understand the limitations and nature of science; 3) gain skills of investigation, scientific and technological formulation; 4) develop the process of thinking and imagination, and the ability of problem solution and management, communication skills, and the ability to make decisions; 5) recognise the relationship among science, technologies, human beings, and environments in terms of influence and affectation; 6) apply the knowledge of science and technology to make it useful for society and for living; and 7) have a scientific mind, ethics, and value in the original use of science and technology. Like Finnish science education, the Thai science curriculum also recognises how to make the students attain these teaching purposes in their science learning. For this reason, Thai primary school teachers in every grade level have the main responsibility for this important task (Ministry of Education, 2008).

4.2 Method

4.2.1 Analysis framework of science curricula at primary level

The aims for science education in the Finnish and Thai science curricula are presented in different ways: Finnish aims are presented in the form of broad aims for teacher teaching and Thai aims are descriptions of learning outcomes. To have an independent and general view in the content analysis of the primary science curriculum, the PISA 2006 Scientific Literacy Framework (OECD, 2006) or, in its short form, the PISA Science Framework', was used as an analytical frame for the analysis.

The 2006 PISA Science Framework (OECD, 2006) defines three competency fields that describe the use of content knowledge in science and knowledge about science and the willingness to use this knowledge (attitude) in three situations: in identifying scientific issues, in explaining scientific phenomena and in drawing evidence-based conclusions. The description of each area of competency is shown in Figure 2.

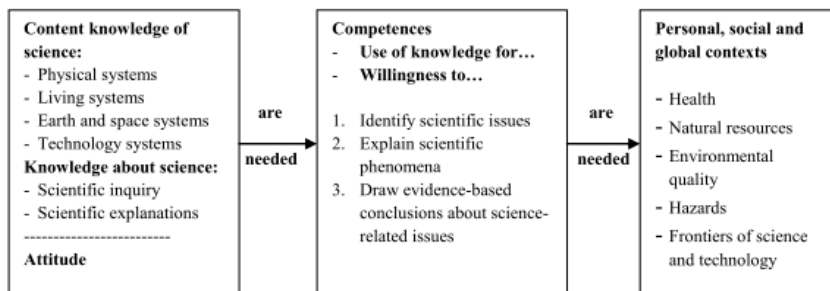


Figure 2. Aspects of the PISA Scientific Literacy Framework.

Three main aspects (*competences, contents, contexts*) are emphasised in the PISA 2006 Science Framework (OECD, 2006). This framework is used for science tests and item design. There are components under each aspect; for example, the competence aspect, the first main category, emphasises the content knowledge as being classified into two sub-categories: *knowledge of science* and *knowledge about science*. The first sub-sub-category in the ‘*knowledge of science*’ includes both physics and chemistry knowledge.

The second main category is defined in terms of an individual’s *scientific knowledge* and use of that knowledge to *identify scientific issues, explain scientific phenomena* and *draw evidence-based conclusions*. I included in the first sub-category, ‘*identify scientific issues*’, which involves planning and implementing scientific inquiry; therefore, practical work in a science curriculum was assigned to this sub-category. The second sub-category, ‘*explain scientific phenomena*’, includes descriptions in a curriculum that refers to the use of knowledge, such as problem solving in science. The third sub-category, ‘*draw evidence-based conclusions*’, includes the use of different types of information available in texts, tables or experiments.

The last main category used in the content analysis focuses on the contexts. The PISA 2006 science questions were framed within a wide variety of life situations involving science and technology. Consequently, the contexts used for questions were chosen according to the relevance to students’ inter-

ests and lives, representing science-related situations that adults might encounter. The detail on all three aspects is shown in Figure 3.

1. Content Knowledge	
Knowledge of science	Knowledge about science
Physical systems: Structure of matter; Properties of matter; Chemical changes of matter; Motions and forces; Energy and its transformation; Interactions of energy and matter	Scientific inquiry: the central process of science and the various components of that process.
Living systems: Cells; Humans; Populations; Ecosystems; Biosphere	Scientific explanations: the results of scientific enquiry.
Earth and space systems: Structures of Earth systems; Energy in Earth systems; Change in Earth systems; Earth's history; Earth in space	
Technology systems: Role of science-based technology; Relationships between science and technology; Concepts; Important principles	
2. Competences	
Identify scientific issues includes planning inquiry activities and the collection of data. Identifying verbs are those such as observe, experiment, inquiry, investigate	
Draw evidence-based conclusions includes the use of textual, pictorial or tabular information in drawing conclusions. Identifying verbs are those such as interpret, explain, discuss, make, formulate	
Explain scientific phenomena includes applying knowledge of science or knowledge about science in a given situation. Identifying verbs are those such as apply, use, describe, solve	
3. Contexts (personal, social, and global)	
Health: maintenance of health, accidents, nutrition, epidemics, spread of infectious diseases	
Natural resources: populations, quality of life, security, renewable and non-renewable energy sources, natural systems	
Environmental quality: population distribution, disposal of waste, environmental impact, local weather, biodiversity, ecological sustainability, control of pollution	
Hazards: rapid changes, climate change, impact of modern warfare	

Figure 3. Three main aspects of the PISA scientific literacy framework.

4.2.2 Content analysis of the Finnish and Thai curricula

While analysing the curriculum text, I followed the Weber (1990) and Neuendorf (2002) example of content analysis. The analysis proceeded in the following steps:

1. I identified the main categories and sub-categories and wrote the definitions for categories based on the PISA 2006 Science Framework. Therefore, the analysis can be characterised as deductive.
2. I classified the textual information from both science curricula at primary level according to main categories and sub-categories (see Appendices C and D). Altogether, there were 10 standard pages in the Finnish curriculum and 20 pages in the Thai curriculum. One sentence might include several ideas. Therefore, one sentence could belong to more than one category.
3. I made tables based on the content analysis to calculate the frequency and percentage of each category defined by the PISA 2006 Science Framework.
4. After the content analysis, I employed a non-parametric test to compare the science curricula.

To obtain credibility for this sub-study, the curricula texts were analysed by the author and two other researchers in this step. The classification process (step 2) started by recognising units used in both curricula texts. We recognised that it was most appropriate to take one single idea as a unit of analysis; therefore, one sentence was typically divided into several units. However, in one unit, typically at least one competence and one content area or a context was mentioned. We recognised this when two researchers were classifying 10% of each curriculum independently. The agreement was on average about 70%. After this trial, I wrote narrower descriptions of the categories and decided on the following procedure:

1. I classified all units in both curricula according to the main categories and sub-categories. Altogether, there were 553 units.
2. The second researcher, familiar with the Finnish context, went through all of the classifications using the track changes tool. He recommended that there should be 135 changes.
3. I reconsidered all of the changes that were recommended by the second researcher.
4. The second and third researchers discussed the recommendations with the author; the recommendations were not accepted until a consensus was reached on the final classifications. Altogether, there were five individual discussions on this aspect.

Therefore, the content analysis was iterative in nature. Table 2 presents an example of the content-analysis outcomes. The process of the iterative nature of the analysis is shown by the crossed-out terms. Finally, the percentages of each category were calculated based on the content analysis of the study and were demonstrated by 100% stacked bar charts.

Table 2. Outcome of the Content Analysis by the Second Researcher

Textual Information	Knowledge of Science:	Knowledge about Sci-ence:	Competence	Context
The learning area of science is aimed at enabling learners to learn this subject with emphasis on <i>linking knowledge with processes</i> , acquiring essential skills for investigation, building knowledge through <i>investigative processes</i> , seeking knowledge and <i>solving various problems</i> . [<i>Solving problems means use of knowledge.</i>]		nature of scientific inquiry nature of scientific inquiry <u>nature of scientific explanations</u> [new] nature of scientific inquiry [deleted]	identify scientific issues identify scientific issues <u>explain scientific phenomena</u> [new] identify scientific issues [deleted]	
Learners are allowed to participate in all stages of learning, with activities organised through diverse <i>practical work suitable to their levels</i> .			<u>identify scientific issues</u>	
The main content areas are prescribed as follows: living things and processes of life; basic units of living things; biodiversity; genetic transmission; functioning of various systems of living things; evolution and diversity of living things	living systems living systems living systems living systems living systems living systems			natural resources Environmental quality health natural resources

4.3 Results

The results of the theory-driven content analysis, where the PISA 2006 Scientific Literacy Framework was used as a framework for the analysis, are presented next. The textual information for analysis amounted to 30 standard pages and 553 analytical units divided into 156 units in the Finnish science curriculum and 397 units in the Thai science curriculum. The outcomes of deductive content analysis are described in Figures 4–7.

4.3.1 Knowledge of science

Figure 4 summarises the knowledge of science in both curricula. The analyses revealed that the main emphasis was on physical and chemical systems and living systems in both countries. In the Finnish curriculum, the study of living systems was more strongly emphasised at twice the level compared to the Thai curriculum. Examples of knowledge areas that were not related to any PISA categories were aims/learning outcomes emphasising social relations between human beings or aims emphasising only science inquiry procedures. In Finland, geography is integrated with science. Therefore, the Finnish science curriculum introduced geography content such as Europe as a part of the world, the map of Europe, Europe's climatic zones, vegetation zones and human activity; all of these topics can be categorised in some aspects of the PISA Science Framework, but not all. Thus, there were some topics that were not strictly science, such as the *world map's main nomenclature* and *map skills*, and consequently, they were not used as a part of the calculation in the analysis.

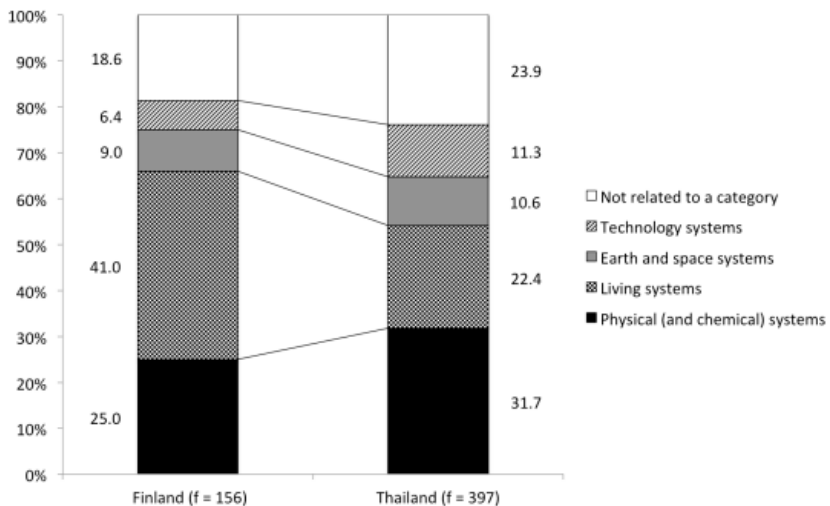


Figure 4. The comparative percentages of the sub-categories in the knowledge of science category.

4.3.2 Knowledge about science

The Finnish and Thai percentage distributions for knowledge about science differ insignificantly (Figure 5). There were several aims that could not be classified in the categories related to the ‘*Knowledge about science*’ category. The percentages show the same pattern of frequencies in both countries. However, both categories were under represented in the Finnish curriculum.

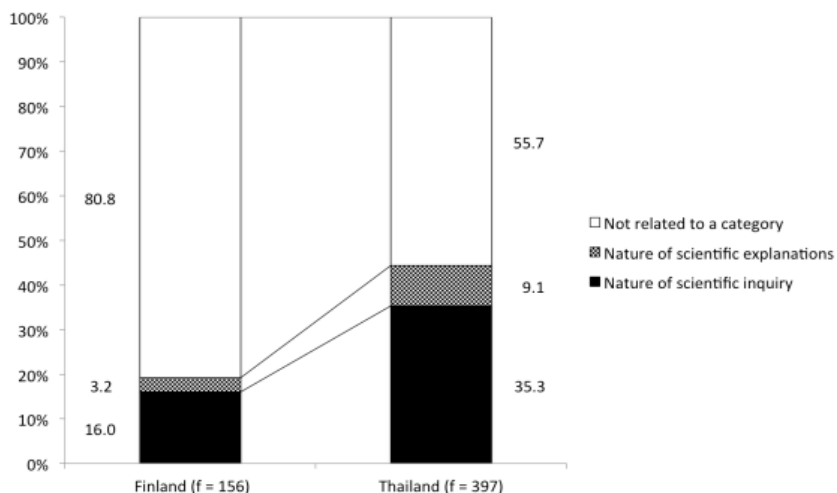


Figure 5. The comparative percentages of the sub-categories in the knowledge about science category.

4.3.3 Science competences

The percentages for PISA competence are shown in Figure 6. The Finnish and Thai percentage distributions differ significantly. *Identify scientific issues* ($f = 31.7\%$) and *Draw evidence-based conclusions* ($f = 26.2\%$) were used mostly in the Thai science curriculum with the approximate percentages. In Finland, the percentages of *Draw evidence-based conclusions* was seldom seen as an aim compared to other competences ($f = 5.8\%$). In general, in Finland, three PISA science competences were indicated among the aims much less frequently than in the Thai curriculum: In Finland, 57% of the aims were not focused on the three PISA science competences.

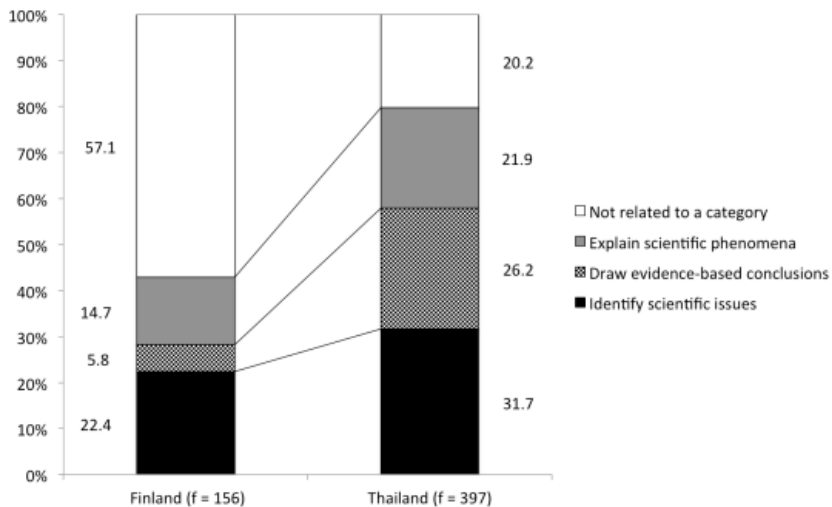


Figure 6. The comparative percentages for competence analysis in the Finnish and Thai science curricula.

4.3.4 Contexts

The frequencies of the contexts where the aims or contents were presented in the Finnish and Thai science curricula are shown in Figure 7. In the Finnish curriculum, there were more rich contexts (compared with the total number in the textual information analysis) indicated in the curriculum than in the Thai curriculum.

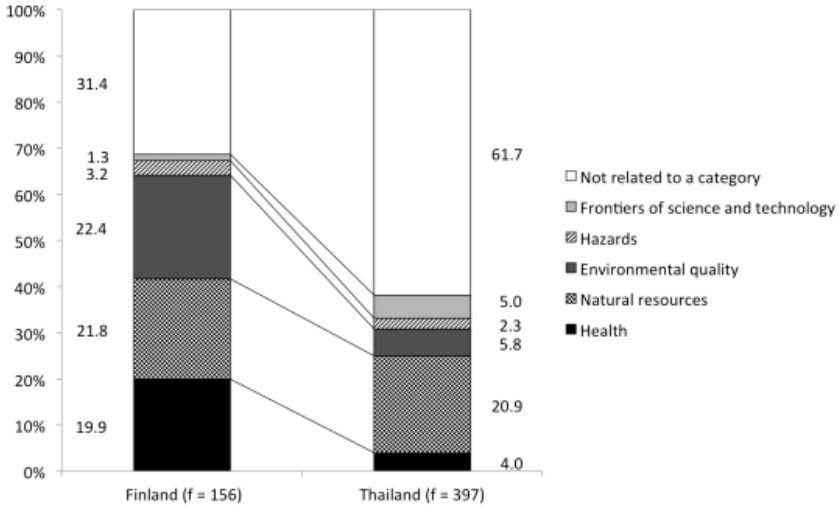


Figure 7. The comparative percentages for context use in the Finnish and Thai science curricula.

It is notable that the Finnish and Thai distribution differed significantly, as shown in Figure 7. The first three groups of contexts aligned closely with the percentages in the Finnish science curriculum. In Thailand, *Not related to a category* had the highest percentage compared to other categories ($f = 61.7\%$). In the Finnish curriculum, *Environmental quality* and *Health* contexts were presented much more frequently than in the Thai science curriculum. In the Thai curriculum, *Contexts of natural resources*, *Frontiers of science and technology* and *Hazards* were used more often than in the Finnish science curriculum. In the Finnish curriculum, only one percent of content was classified in the category of the *Frontiers of science and technology* context.

4.4 Discussion

In Finland, the science curriculum at the primary level introduces science through three main subjects: environmental and natural studies (in grades 1–4), biology and geography (in grades 5–6) and physics and chemistry (in grades 5–6). However, science in grades 1–6 in Thailand is taught through one science subject: science. The Finnish environmental and natural studies category is rather similar to the science category in Thailand. In general,

based on my reading and content analysis, the Thai and Finnish curricula emphasise the same topics, such as scientific concepts and processes, scientific skills, the use of scientific knowledge, nature, environments, technology and science in society.

There were ambitious topics in the Thai science curriculum that were not found in the Finnish curriculum. For example, the instructions to *discuss* effects on living organisms from environmental change due to both nature and human beings, to *analyse and explain* the changes resulting in the transition of substances to new substances with different properties and to *explain* substance changes affecting living things and the environment. These are really challenging aims for grade 6 students. Moreover, the Thai curriculum emphasises the ability to *apply knowledge* for useful purposes and to *pose new questions* for subsequent exploration and verification several times through repetition. These qualities again reflect the fact that the Thai science curriculum took the competence aspect in the PISA Science Framework into consideration, while the Finnish curriculum showed all results under the four categories of the analysis framework to be more balanced.

4.4.1 Main outcomes from the content analysis

The Finnish and Thai curricula could be analysed following the PISA Science Framework, although the aims in the curriculum have been described in different ways: Finnish aims are presented in the form of aims for teacher teaching and Thai aims as descriptions of learning outcomes.

There were approximately three times more texts in the Thai curriculum document than in the Finnish curriculum document. The relative emphasis on certain content areas in the Finnish and Thai curricula was rather similar. However, the *Living systems* content was most emphasised in the Finnish science curriculum, while *Physical systems* was the largest content area in the Thai science curriculum. In Finland, the topic *Nature of scientific explanations* had a lower frequency than in Thailand. The topic *Nature of scientific inquiry* in the Thai curriculum had the highest frequency among the sub-categories in both countries. The competence results showed that all three sub-categories of competences had equal frequency in the Thai curriculum. In Finland, the topic *Draw evidence-based conclusions* had the lowest frequency and *Identify scientific issues* had the highest. In general, the Finnish curriculum emphasised more contexts than the Thai curriculum. The context of *Environmental quality* was used most in both science curricula.

The Thai curriculum has an increased emphasis on the scientific process rather than on scientific concepts (cf. Chandavimol, 1990). On the other hand, the Finnish science curriculum emphasises the concepts and contexts in

which these concepts meet, rather than the process. According to Bransford, Brown and Cocking (2000, p. 9), experts' abilities to think and solve problems is tied to a rich body of knowledge about the subject matter. With this knowledge, experts can notice features and meaningful patterns of information acquired from such sources as the Internet. Therefore, it is not straightforward to blame the teaching of concepts instead of science process skills. An interesting question is what is the optimal balance for the teaching of concepts and processes?

The Thai science curriculum provided concepts and competences often without contexts, *Not related to a category*, while the Finnish curriculum had approximately a 20% frequency for the topics of *Health, Natural resources and Environmental quality*. It is clear that the context in the PISA 2006 Scientific Literacy Framework cannot cover all of the used contexts that satisfactorily align with the content knowledge (four systems). For example, *Forces and motion (forces acting on objects (Thai); motion of objects (Thai), and Energy (various ways of producing electricity and heat (Finnish); properties and phenomena of light, and sound (Thai))* were topics that were introduced mainly without context in both science curricula. However, an emphasis on context is important from the point of view of learning. Bransford, Brown and Cocking (2000) emphasise that the meaning of concepts becomes broader if a student meets the concept in different contexts. Moreover, the context has an influence on student interest (Cordova & Lepper, 1996; Bennett, Hogarth, & Lubben, 2003).

4.4.2 The number of lesson hours indicates the importance of science as a school subject

Science is one of the major subjects in most education systems throughout the world. The organisation and time allocation for science teaching reflects the importance of science from the point of view of everyday and working life situations. In Finland, in grades 1–6, there are 400 science lessons in total. Moreover, in Finland, the time allocation for science also includes the topics of geography and health education; and, therefore, less than 400 hours are allocated to the specific science subjects of biology, chemistry and physics in Finland. In Thailand, the time allocation for primary school science education is 480 lessons. A comparison with other countries is rather difficult, because subjects are organised very differently in different countries. Thus, in comparison, the number of science lesson hours is higher in Thailand than in Finland.

4.4.3 Curriculum and the PISA

The PISA 2009 results (OECD, 2010) demonstrate that Finnish students are among the highest and Thai students among the lowest performing students in the PISA survey. Several researchers and scholars have studied the PISA framework and the PISA outcomes (Anderson et al., 2007; Rodger, 2009; Neumann, Fischer, & Kauertz, 2010; Drechsel, Carstensen, & Prenzel, 2011). Although this study focuses on primary science curricula, it belongs to PISA-related research.

Finnish and Thai primary science curricula have several aspects similar to the PISA Science Framework. Therefore, it is understandable that Finnish students' success in PISA has been previously explained partly by similarities between the Finnish curriculum and the PISA Science Framework (Lavonen & Laaksonen, 2009). However, the analysis presented in this sub-study revealed that the Thai curriculum was more similar to the PISA Science Framework than the Finnish curriculum was. Therefore, the implementation of the intended curriculum, for example, by teachers and textbook authors (the hidden, implicit or covert curriculum) could be more important for PISA success than the national-level curriculum as such. Nor does the number of lesson hours in science explain the results as such: Thai students spend more time in learning science than the Finnish students do.

Possible reasons for the differences in PISA performance could be the availability of qualified science teachers, the student–teacher ratio and the average class size. According to the PISA Thailand Project & IPST (2009), there were 30 percent of non-qualified science teachers in Thai schools. The OECD average for the student–teacher ratio in primary classes is approximately 11–16 students per teacher (OECD, 2011), while the Thai teacher has about 25 students (Atagi, 2011). In Thailand, the average primary class size is 50 students per class (Wößmann, 2003). In Finland, the average class size is fewer than 20 students per classroom (OECD, 2012). Consequently, the number of students in a classroom certainly affects how much time the teacher is able to spend focusing on individual students and their specific needs rather than on the group as a whole. Furthermore, this ratio can also matter for student achievement (Ehrenberg et al, 2010).

A prominent issue that has to be taken into account is that the PISA assessment is for 15-year-old students, but this sub-study presents the comparative analysis of the curriculum for students at the primary level. However, the primary curriculum differs substantially in Finland and Thailand; therefore, a neutral frame is needed. Referring to the science curricula analysis, the results showed that the contents of both Finnish and Thai science curricula at

the primary level were in accordance with the PISA 2006 Scientific Literacy Framework, but that the Thai curriculum fitted it better.

This better fit is a consequence of the active role of the Institute for the Promotion of Teaching Science and Technology (IPST), which has been responsible for science education in the Thai nation. The IPST emphasises certain aspects for quality science teaching. They are an inquiry-based teaching/learning process, a higher order thinking process, a scientific process and the use of information technology (IT) for teaching and learning (Boonklurb, 2000). The issues that have been emphasised are close to those of the PISA Scientific Literacy Framework.

4.5 Conclusions

The most interesting findings in my content analysis deal with the balance between concepts and processes. The Thai curriculum emphasises PISA-related processes, while the Finnish curriculum emphasises concepts. Another interesting finding is related to contexts. The Finnish curriculum emphasises contexts more than the Thai curriculum does. An appropriate context supports both learning and interest. However, the hidden or implicit curriculum or the way in which qualified and unqualified teachers as well as textbook authors implement the curriculum has an influence on the learning outcomes. Consequently, both teachers and textbook authors should think about the balance between the learning of concepts and processes. Secondly, both should carefully think of the contexts through which they introduce concepts and processes. Moreover, the school context, such as the number of students in the classroom, has an influence on outcomes.

Some ideas coming out from this study could lead curriculum planners or science educators to design the science curriculum through the perspective of the PISA Scientific Literacy Framework in the future.

5 Comparative Study II: An analysis of Finnish and Thai science textbooks

The latest Finnish follow up of assessment in the natural sciences shows, altogether that 79% of teachers indicate that they use a science textbook in every lesson or almost every lesson (Kärnä, Hakonen, & Kuusela, 2012). From PISA (OECD, 2007) school-questionnaire data, 76.2% of Thai headmasters and 74.7% of Finnish headmasters claim that there is only a slight or no shortage of science textbooks. Consequently, textbooks seem to be important in both countries.

Textbooks play a vital role in conveying concepts (subject matter), natural laws and theories to students. The quality of understanding or understanding the meaning of a concept is related to the capacity to use and apply the concepts in familiar and new situations (Gott & Duggan, 1995, pp. 25–26). Therefore, when introducing a concept in a textbook, it is essential to make clear how the concept is related to other concepts, physical laws and principles. Mintzes and Wandersee (1989) emphasised the relations between concepts and the role of examples when introducing concepts through a concept map. When examples and/or non-examples in the concept's domain are given, the concept should be constructed through a classification activity (Joyce & Weil, 1980, pp. 25–60). In addition to the learning of conceptual knowledge, textbooks support the learning of procedural knowledge or processes (McCormick, 1997). Casteel and Isom (1994) stated:

The literacy processes produce comprehension and the communication of ideas, and these are manifested through reading, writing, listening, speaking, and thinking. These processes in turn support the development of science process skills necessary for gaining the knowledge and understanding of the physical world. (p. 540)

Therefore, one way for students to attain the required procedural knowledge and develop process skills is through reading a textbook.

Bransford, Brown and Cocking (2000) argue that when students are reading a textbook, their previous knowledge interacts with the information, text and pictures available to influence comprehension and recall. In addition, Chiappetta and Fillman (2007) summarise that at all levels of science education, textbooks are often used as the primary organiser of the subject matter that students are expected to master and that the books provide detailed explanations of the topics to be taught. Therefore, textbooks play an important role in offering credible information. The students are supposed to learn through processing this information. Ideas supporting constructivism are well

documented by research on the comprehension of the written text and it has been concluded that reading is a process involving the active construction of meanings (e.g., Spiro, 1980; Bransford, 2000). Therefore, textbooks play a vital role in science teaching and learning (e.g. Strangman et al., 2003; Abd-El-Khalick, Waters, & An-Phong, 2008).

What is inside textbooks? All representations in a textbook – such as text, pictures, diagrams, charts, models, tables and graphs – are used for communicating ideas and concepts (Roth & McGinn, 1998, p.35). There is plenty of research on representations in several fields such as mathematics, physics and biology. The representations in textbooks have been categorised from different perspectives. For example, Carolan, Prain, and Bruce (2008) suggested that the diverse representations used in teaching and learning science should be divided into two groups: one of them can be further categorised as specific to the domain of science (such as 3D models, tables, graphs, diagrams, science journals, multimodal reports, and appropriate vocabulary and measurement for specific topics).

Focus on the text in the textbook, the text-based learning research on a situational interest or positive attitude is the result of certain text characteristics or the context where the text has been presented (Hidi & Baird, 1986; Krapp, 2002). Consequently, the context where the textual or pictorial information is presented or how the relevance of the topic is demonstrated could have an influence on the development of a student's attitude. Especially, context-based approaches have had an influence on textbooks in terms of stimulating young people's interest in science and helping them to see how it relates to their everyday lives (Bennett, Hogarth, & Lubben, 2003). As student interest is extremely important to future involvement in the subject, it is useful to know how textbooks emphasise the different contexts. Research has identified several factors that interrelate with the development of a positive attitude towards the learning of science, such as the perceived relevance of science from the point of view of everyday life, further studies or occupation, and the interestingness of the content or the context where certain science content or topics is delivered (Simon, 2000; Osborne, Simon, & Collins, 2003).

In what follows, the summary of the above aspects as essential features of textbooks are introduced. They are used as main categories in the content analysis of Finnish and Thai science textbooks. A science textbook:

- emphasises conceptual and procedural knowledge in a form students are able to learn from,
- supports meaning making while introducing new knowledge,
- uses different representations while introducing the knowledge, and

- supports the development of a positive attitude to science through demonstrating the relevance of science and the use of appropriate contexts when introducing new knowledge.

5.1 Research Questions

The research questions are:

1. How are science concepts introduced in Finnish and Thai primary science textbooks?
2. To what extent do Finnish and Thai science textbooks emphasise the learning of conceptual and procedural knowledge?
3. What kinds of representations do textbooks use to clarify science concepts?
In which contexts are the concepts introduced?

5.2 Methods

This research is part of a comparative study where science education is compared in high- and low-performing countries, measured with the PISA Scientific Literacy Assessment Scale (OECD, 2007). To analyse Finnish and Thai primary textbooks, the chapters to be analysed have to be selected carefully. Therefore, the selected chapters focused on electric circuit in primary textbooks. Electric circuit is introduced in the national core curriculum of both countries and is a common topic for teaching worldwide; furthermore, this topic can be taught in terms of the conceptual and practical levels, especially as it definitely relates to students' everyday phenomena and society as well. Duit and Rhöneck (2001, p. 1) suggested that: 'Electricity is one of the basic areas of physics which is important at all levels of physics teaching. At the primary level young children have already gained experience with simple electric circuit.'

In Finland, science textbooks are produced by private publishing companies. In an author group, there are science-education researchers, teacher educators and school teachers. The Finnish textbook was chosen because of its widespread use in schools. In Thailand, the selected book is published by the Ministry of Education and authored by a committee of consultants from various professional education groups. The analysed book is used in most of the public schools in Thailand. Altogether 6 pages in the Finnish and 12 pages in the Thai textbooks were selected for analysis.

The study can be characterised as qualitative content analysis. According to Neuendorf (2002, p. 10),

Content analysis is an in-depth analysis using quantitative or qualitative techniques of messages using a scientific method and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented.

Weber (1990) stated that content analysis refers to a method of transforming the symbolic content of a document, such as words or images, from a qualitative, unsystematic form, into a quantitative, systematic form. I used non-parametric tests in comparing the textbooks. Similar to the science curricula analysis (Section 4.2), the textual and pictorial information in the textbooks were analysed by me and another researcher to add credibility to the study. The analysis steps are described below:

1. I translated the electricity chapters in textbooks into English and then read them several times to select the text corpus for the analysis.
2. I identified the main categories and sub-categories and wrote the definitions for the categories based on the literature review and the content of the textbooks. Therefore, the analysis can be characterized as deductive.
3. I made a list of all physics terms introduced in the selected chapters to determine the concepts introduced in each chapter.
4. I classified the sentences, phrases and pictures covering the selected concepts according to the main categories and sub-categories (see Appendices E and F). There were typically several concepts in each sentence. Another researcher classified all the information independently from the textbooks.
5. We discussed the recommendations that one of us did not accept until we decided on the final classifications by consensus.
6. The percentages for each category were calculated based on the content analysis, and the non-parametric test (chi-squared test: χ^2) was used. A chi-square (χ^2) statistic was used to investigate whether the distributions of categorical variables differed from one another. The chi-square test is inappropriate if any expected frequency is below 1 or if the expected frequency is less than 5 in more than 20% of the cells. (Greenwood & Niskulin, 1996)

Sub-categories were defined inductively in phase 2 of the study process. After the preliminary reading (phase 2), the following main categories were defined:

Introduction of concepts: The way the concepts are introduced to the students.

Type of knowledge: Text and figures emphasising the learning of procedural knowledge or conceptual knowledge.

Representations: All the textual and pictorial information in the analysed chapters. This indicates which types of figures, pictures or drawings are used to introduce the concepts to the students.

Contexts: Concepts in the textbooks are presented in different contexts.

5.3 Analysis framework

In what follows, I define in more detail the main categories and sub-categories of the textbook analysis.

5.3.1 Introduction of concepts

Many authors in the philosophy of science have suggested that the concepts of physics should be seen as structures or networks rather than logically or semantically defined entities (Thagard, 1992; Nersessian, 1995). Therefore, when introducing a concept in a textbook, it is essential how the concept is related to other concepts, physical laws and principles. Classification is a natural process in science: physical phenomena can be classified into motion, electric, thermal and sound phenomena. Respectively, the attributes of materials can be classified into mechanical, electrical, optical and acoustic attributes. Consequently, a science textbook could support concept formation through giving examples and supporting classification. Furthermore, textbooks also use metaphors and analogies to help students to develop a meaning linked to a new concept, especially when the concept is abstract and outside their previous experience. Metaphors and analogies are comparisons between the new concept and already known concepts that have some particular things in common. Links between the new concept and known concept are constructed with shared and unshared attributes and this is called mapping. Metaphors and analogies typically include phrases such as, 'It's just like', 'It's the same as' and 'It could be compared to' (Duit, 1991; James & Scharmann, 2007).

As a summary, a concept could be introduced in a textbook through an example or examples, through describing the relationship between a new concept and already existing concepts or through a metaphor or an analogy. If the concept has already been introduced in a previous chapter, then the concept is typically just used. Sometimes the concept is just used without any definition (Table 3).

Table 3. Definitions of the Categories and Examples of the Original Expressions

Category	Definition of the Category	Examples of Original Expressions
Analogy	A concept is introduced by a metaphor or an analogy. A comparison between the new concept and already known concepts that have some particular things in common is done.	<i>Flash of lightning and the glow of a light bulb are similar phenomena.</i> <i>The wall socket has two poles, which are equivalent to the poles in a battery.</i>
Example	A textbook supports concept formation through giving examples or through supporting classification.	<i>Button batteries are used in watches, cameras and calculators.</i> <i>The voltage between the poles is 230 volts.</i>
Relation	A concept is related to other concepts, physical laws and principles.	<i>One pole of a battery is called the plus pole (+).</i>
Introduced earlier	The concept is introduced earlier, for example in a previous chapter.	<i>The unit of voltage is volt (V).</i>
Just used	The concept is just used without any definition.	<i>They can be recharged with a battery charger that is connected to a socket.</i>

5.3.2 Type of knowledge

Any information such as texts and pictures is presented in the textbook so as to emphasise the students' learning (cognitive domain) and developing interest (affective domain). In what situations does textual and pictorial information emphasise the learning of conceptual or procedural knowledge for students? I have two categories here: conceptual and procedural knowledge (Anderson & Krathwohl, 2001). Conceptual knowledge is static knowledge and it includes facts, concepts and principles that could be applied in a certain domain (de Jong & Ferguson-Hessler, 1996). Anderson and Krathwohl (2001) categorised it into three sub-domains: knowledge of classifications and categories; knowledge of principles and generalisations; and knowledge of theories, models and structures. Procedural knowledge is knowledge of how to do something, methods of inquiry and criteria for using skills, algorithms, techniques and methods (Spivey, 2007). It is the knowledge required to perform a task; knowledge that can be applied directly and is most often represented as production rules (Tobias & Duffy, 2009). It helps the problem solver make transitions from one problem state to another (de Jong & Ferguson-Hessler, 1996). Anderson and Krathwohl (2001) categorised it into three sub-domains: knowledge of subject-specific skills and algorithms; knowledge of subject-specific techniques and methods; and knowledge of criteria for determining when to use appropriate procedures. The PISA 2006 Scientific Framework (OECD, 2006) combines conceptual and procedural types of knowledge and

defines three broad competencies in terms of an individual's scientific knowledge and use of that knowledge to identify scientific issues, explain scientific phenomena and draw evidence-based conclusions. These broad science competencies could also be understood as categories for procedural knowledge and are useful for planning science teaching and textbooks in addition to the planning of science items for international measurements.

5.3.3 Representations

A concept could be introduced through a text or through a picture. Therefore, all textual and pictorial information in the analysed chapters was classified based on the type of representation in two main categories: *textual representation*, which includes all kinds of texts, and *pictorial representation*. Pictorial representations aim to assist students in terms of conceptual explanations. They can expand the meaning-making potential of the texts. In addition, Gardner (1993 cited in Zambo, 2006) suggested that picture books are unique learning tools because they provide both words and images, and these multiple modes of input tap varied learning styles. To analyse the pictorial representations in the science textbooks, their classifications were divided into two dimensions: type and function, following Dimopoulos et al. (2003). The line drawings and manipulated pictures were added to the original categories because they occur in the analysed textbooks and all representations are presented in Table 4.

Metaphorical representations are the visual representations that ‘connote or symbolize meanings and values over and above what they literally represent’.



‘Celsius and thermometer’ (Alexopoulos, B. et al. (1989). *Science for primary school*. Athens, Greece: OEDB, p. 55 cited in Dimopoulos et al. 2003).

5.3.4 Contexts

A context is a situation or a background where a concept is met. For example, when a student looks at the picture, he/she could link his/her own ideas with the science content. For example, a picture where a student is pushing a remote control recalls an experience of turning on or switching off a television. This picture in the context of a closed circuit supports the meaning making for the closed circuit and, consequently, helps students to apply that concept in their everyday lives. For this reason, a particular context and students’ interest go together with the same direction of interest enhancement. In addition, Hoffman (2002) notes:

While the interestingness in physics instruction depends on situational conditions, such as the particular context in which a topic of physics is presented and particular activities students are allowed to engage in the social climate is characterized by conditions of teacher-to student and student-to-student interactions. (p. 448).

Juuti et al. (2004) surveyed student interest using the following six categories: the ideal context; science and technology in society (STS) context; technical applications context; and constructing context. They found that topics in one context were often more interesting than those in other contexts. Further, there are gender differences between contexts. In addition to these contexts, the historical situation could be a context. I will apply the following context classification in the analysis:

- Human being context; investigation context; and the technology, design
- Ideal context: the concept is introduced through an intangible situation – or a circumstance.
- STS context: the concept is introduced through the relationships between the use of a concept or an application related to the concept and society.
- Technical applications context: the concept is used in a situation of technical application use.
- Human being context: the concept is introduced relating to our physical state or an activity a human being is conducting.

- Historical context: the concept is introduced through explaining how and/or who brought the concept into use.
- Investigation context: the concept is introduced by an investigative method such as observation in the classroom, hands-on activities or doing and experiment.
- Design and constructing context: the concept is introduced for designing and constructing something in any situation.

5.4 Results

The results of the analysis are presented according to the research questions. The first question focuses on the physics concepts related to electric circuits in grade 6 that have been introduced. Table 5 presents the common and dissimilar concepts in the two textbooks.

Table 5. Physics Concepts Related to Electric Circuits in Finnish and Thai Textbooks

Common Concepts	Concepts only in the Thai Textbook	Concepts only in the Finnish Textbook
Battery	Alternating current	Accumulators
Circuit diagram	Direct current	Ampere
Closed circuit	Electric bell	Break
Conductor	Motor	Charger
Electric circuit		Chemical energy
Electric current		Electric charges
Electric devices		Flashlight
Electricity		Fuse
Energy		Light
Filament		Plug
In parallel		Socket
In series		Thermal
Lamp		Volt
Light bulb		
Minus pole		
Open circuit		
Plus pole		
Poles		
Resistors		
Short-circuit		

Switch

Voltage

Wire

Total= 23**Total = 4****Total= 13**

Concepts were introduced through different representations and contexts. Altogether, 36 concepts were presented 354 times in the Finnish textbook and 27 concepts were presented 228 times in the Thai textbook. Table 6 presents the most frequently seen concepts in the Finnish and Thai textbooks. The percentage indicates the frequency of a concept from among all of the concepts in the textbook.

Table 6. The Frequency of the Five Most Used Concepts in the Finnish and Thai Textbooks

The five most used concepts in both textbooks	Finland		Thailand	
	<i>f</i>	<i>f</i> (%of all concepts)	<i>f</i>	<i>f</i> (%)
Battery	60	10.3	42	7.2
Electric circuit	8	1.4	16	2.7
Electric current	31	5.3	14	2.4
Lamp	31	5.3	41	7.0
Wire	19	3.3	15	2.6
Total (N _{of all concepts} = 582)	149	25.6	128	22.0

$$\chi^2 = 10.6, p < 0.05$$

Battery was used most frequently, then lamp and electric current in both textbooks. The Thai textbook introduced electric circuits more often than the Finnish textbook (twice as frequently), whereas the electric current was introduced twice as much in the Finnish textbook than in the Thai textbook. However, the frequency distributions were not statistically significantly different. Both countries introduced the concept of wire with almost similar frequencies.

5.4.1 Introduction of the concepts

The frequencies of the ways of introducing the concepts are described in Table 7. The Finnish and Thai frequency distributions were statistically significantly different ($\chi^2 = 13.8, p < 0.01$).

Table 7. Comparison between how concepts were introduced in the Finnish and Thai textbooks

Introduction of the concepts	Finland		Thailand	
	<i>f</i>	<i>f</i> (%)	<i>f</i>	<i>f</i> (%)
analogy	8	2.3	0	0
example	37	10.5	49	21.5
introduced earlier	22	6.2	16	7.0
just used	26	7.3	27	11.8
relation	261	73.7	136	59.6
Total (N = 582)	354	100	228	100

$\chi^2 = 13.8$, $p < 0.01$ (categories were combined in order to have no zero frequencies)

5.4.2 Type of knowledge

Table 8 summarises the analysis of the type of knowledge that the textbooks emphasised. The analyses revealed that the learning of procedural knowledge was emphasised more often in the Thai textbook than in the Finnish textbook ($\chi^2 = 19.7$, $p < 0.001$). The most frequently used concept in both countries was a battery, but in Thailand, it was more often used to emphasise couplings or other procedures than in the Finnish textbook. In the Thai textbook, a lamp was also used in situations where procedural knowledge was emphasised more often than in the Finnish textbook.

Table 8. Emphasising the type of knowledge from the Finnish and Thai textbooks when students read through pictorial and textual information in the textbooks

Type of Knowledge	Finland		Thailand	
	<i>f</i>	<i>f</i> (%)	<i>f</i>	<i>f</i> (%)
Conceptual	315	89.0	171	75.0
Procedural	39	11.0	57	25.0
Total (N = 582)	354	100	228	100

$\chi^2 = 19.7$, $p < 0.001$

5.4.3 Representations

Table 9 presents the number of representations used in the Finnish and Thai textbooks. The Finnish and Thai frequency distributions were statistically significantly different ($\chi^2 = 23.9$, $p < 0.001$). I also examined the representa-

tions of ‘battery and lamp’ in the Finnish and Thai textbooks. The most frequently used representations for the battery in Finland and in Thailand was the textual form ($N_{\text{FIN}} = 55$; $N_{\text{THAI}} = 33$). In Finland, five realistic pictures, and in Thailand, seven realistic pictures and two line drawings were used. The distributions used for a lamp were very similar.

Table 9. Comparison of the Finnish and Thai textbooks: how the concepts were introduced through the representations

Representations	Finland		Thailand	
	<i>f</i>	<i>f</i> (%)	<i>f</i>	<i>f</i> (%)
Analytical	6	1.7	0	0
Hybrid	0	0	1	.4
Line drawing	5	1.4	18	7.9
Manipulated figure	8	2.3	0	0
Realistic figure	14	4.0	36	15.8
Realistic line drawing	6	1.7	0	0
Textual information	314	88.7	173	75.9
Total (N = 582)	354	100	228	100

$\chi^2 = 23.9$, $p < 0.001$ (categories were combined in order to have no zero frequencies)

In addition, the electric current was represented as texts in both textbooks, but more frequently in the Finnish textbook. A manipulated figure was used to demonstrate this concept once in the Finnish textbook and never in the Thai textbook.

5.4.4 Contexts

Finally, I analysed which context was used for introducing the concepts in the Finnish and Thai textbooks. The results are described in Table 10.

Table 10. Comparison of how concepts were introduced through the contexts in the Finnish and Thai textbooks

Contexts	Finland		Thailand	
	<i>f</i>	<i>f</i> (%)	<i>f</i>	<i>f</i> (%)
Historical	3	8	0	0
Human beings	0	0	3	1.3
Ideal	61	17.2	17	7.5
Investigation	0	0	14	6.1
Science, technology, and society (STS)	73	20.6	62	27.2
Technical applications	217	61.3	132	57.9
Total (N = 582)	354	100	228	100

$\chi^2 = 17.3$, $p < 0.001$ (categories were combined in order to have no zero frequencies)

It is notable that the Finnish and Thai distribution differed significantly ($\chi^2 = 17.3$, $p < 0.001$). The order of the most three common contexts was the same in the textbooks. Further, in the Finnish book, there were no concepts relating to human beings or investigative contexts, while in the Thai book there were no concepts in the historical context.

5.5 Discussion

The main finding of the study was that in the Finnish and Thai textbooks, the content of the book chapters focusing on the ‘electric circuit’ could be considered to be rather similar. There were 23 common concepts introduced in the textbooks. In the case of representations, textual representations were used more than realistic figures or realistic line drawings. In the Thai textbook, there were more realistic figures and line drawings, but less text than in the Finnish textbooks. This means that the Thai textbook was more of the picture-book type, while the Finnish textbook emphasised more concepts. The most frequently used contexts were technical applications and STS.

The Thai textbook introduced concepts through procedures more often than the Finnish textbook did. Especially the battery and bulb and other concepts related to electric circuits were introduced in the Thai textbook through explaining how to make the coupling. The descriptions certainly help the students to perform the task as it is; with knowledge that can be applied directly and is represented most often as production rules (Tobias & Duffy, 2009). This approach fitted well with the current trends in science teaching such as the inquiry method, laboratory work, collaborative learning and

hands-on activities. Park, Park and Lee (2009) highlighted the procedural-knowledge emphasis for student learning by investigating in what ways the inquiry-oriented questions or tasks in earth science textbooks reflected the unique characteristics of earth science inquiry methodology in the USA and South Korea. Their results showed that the US textbooks included a small number of inquiry activities and did not introduce features of earth science methodology; in contrast, the South Korean textbooks introduced a large number of activities. However, these teaching methods support students' procedural learning rather than their understanding of the meanings of concepts.

My results concerning the representational analysis showed that the main formats of representations are texts and realistic figures. Realistic figures are always presented along with a textual description or when the important concepts are introduced. Prain and Waldrip (2006) explored the use of multimodal representations of concepts in electricity lessons in primary science. They found that teachers tended to use a diversity of modes (such as verbal, graphic and visual, written and 3D modes) as resources to promote interest in topics. Consequently, both textbooks support teachers in multimodal representational use. Colourful figures were used to draw students' attention and arouse situational interest. Further, well-designed figures can reduce the need for detailed textual information; therefore, well-designed figures may reduce the cognitive load (Yusoof, Sapiyan, & Kamaluddin, 2007; Leavitt, n.d.). Moreover, Plass et al. (2009) showed that any choice of representation in visual learning materials must take into account not only the function of the representation, but also the prior knowledge of the learners who will be using the materials. Therefore, it is important to introduce concepts several times to support the reorganisation of prior knowledge. The cognitive load associated with depictive, descriptive and symbolic representations depends on the learner's prior knowledge.

An important aspect in the PISA 2006 and 2009 Science Framework (OECD, 2006, 2009) are the situations (personal, social and global) and contexts – such as STS – where the science concepts are seen. Contexts in the analysed textbooks seemed to be rather traditional, taking into account what is known about students' interest, especially from the gender perspective (Juuti et al., 2004). After analysing the data from a large national survey, they recommended that textbook authors and teachers should introduce concepts in the context of the human being. They did not report gender differences within this context. The emphasis of technical applications in textbooks is problematic from the gender perspective. The technical application context was most disliked by girls. In general, boys are more interested in knowing how technical applications work than girls are (Aikenhead, 1994, pp. 52–53;

Hoffmann, 2002). In addition, there was an example in the Thai textbook of how a technological context can be combined with a human being context. For example, ‘if we touch the wire without an insulator, electric current will leak and run through our body. ‘We will be dead for this reason’ (Thai textbook, p. 114). The STS context was used in a similar way in both textbooks. Summarising, there are challenges that we have to face in the future to find more versatile contexts through which to introduce electricity concepts.

Both textbooks illustrated the concepts (subject matter) mostly in the context of technical applications with the aim of relating the concept to the students’ lives. From this point of view, students are prone to be interested in and understand a lesson well when that lesson incorporates their experiences. If students are more interested and motivated by the experiences they are having in their lessons, this increased engagement might result in improved learning (Bennett, 2005). Furthermore, the concepts from the textbooks attempted to link students not only with their own lives, but also with new situations that they might encounter. This means that students can apply the idea of each concept to other situations or new situations as well. Yager and Akcay (2008) did action research on STS (science–technology–society), and they found that students could use the information and skills from their own lives in new situations, generating ideas for the use of science concepts in new situations and conversing about science at home.

Another minor observation is that in the Finnish textbook, eight realistic figures were somehow manipulated. For example, some lines were added or some phenomena in the figure were magnified. Manipulation of the figures was made easier by the availability of powerful software, such as Photoshop. Manipulation can be understood as a form of hybrid representation. These manipulated figures are designed so that they emphasise the phenomenon in as clear and as attractive a manner as possible. The aim of manipulation is to make the phenomena easier to perceive. I recommend that the picture captions should indicate whether a figure has been manipulated.

5.6 Conclusion

Based on the findings, some perspectives on science education in both countries were clarified. The Finnish textbook introduced more concepts and also more often described the relations between concepts than did the Thai textbook. On the contrary, the concepts in the Thai textbook were more often presented in a procedural pattern. The main reason for this could be based on the principle that activity organisation provides the means for all learners to draw from authentic experience and that drills in practical skills work for

complete mastery, enabling learners to think critically and acquire the reading habit and continuous thirst for knowledge (Thai National Education Act B.E. 2542, 1999). Therefore, this viewpoint can reflect one aspect of the Thai textbook, in that the concepts were mostly introduced in procedural form and Thai students achieved rather low scores for scientific literacy in terms of scientific knowledge (or concepts) in the PISA assessment. In summary, I believe that some results from this study can be an indicator for further development in science education.

6 Comparative Study III: Primary School Teachers' Interviews

We must give more attention to the interplay between the science of teaching – pedagogy – and the art of teaching ... A teacher must be anchored in pedagogy and blend imagination, creativity and inspiration into the teaching learning process to ignite a passion for learning in student. (Williams, President of the ASCD, 2003 cited in Krause-Phelan et al., 2011)

Science is one of the most difficult subjects for primary school teachers to teach (Musikul, 2007). Teachers feel that school science syllabi are full of scientific concepts, such as entities, models, phenomena and processes. However, they attempt to teach and help the students to understand the concepts by explaining the meanings of the concepts, for example, through giving examples or applications in the domain of the concept. Elluch, Bellamine-Bensaoud and Ben Ahmed (2006) state that teachers should be able to introduce scientific concepts through the use of science learning materials, performing science experiments or using various resources (movies, pictures etc.). To attain learning goals in accordance with the national curriculum, teachers have an important role in scaffolding the students' learning processes. Brandsford, Brown and Cocking (2000) suggest that teachers are the key to enhancing learning in schools.

Teachers employ their knowledge base when they teach students in the classroom. Gess-Newsome and Lederman (1999b) argue that content knowledge, pedagogical knowledge and pedagogical content knowledge (PCK) form the primary knowledge base for teaching. To act as a professional teacher, a teacher should have different kinds of knowledge, not only subject matter or content knowledge, but also knowledge of how to support students' learning. Teachers teach the students how to learn and help them to use the models of learning that will support the best academic, social and personal growth.

Tobin et al. (1990) mention that teaching and learning in the elementary science classroom often focus on recitation and content coverage and that teachers often have limited PCK, especially prospective and novice teachers. The teachers are afraid of unexpected problems when they teach science (Zemble-Saul, Krajcik, & Blumenfeld, 2002). In addition, the report *Science Education in Europe: Critical Reflections* (2008) suggests that the limited range of pedagogy is one of the reasons for students to disengage from science. The main challenge for the teacher is to develop the students' understanding of this body of concepts. At the primary level, ways of constructing

meanings for concepts that rely on a specialist vocabulary of words, symbols, mathematics, diagrams and graphs are difficult for students.

This study focuses on primary school teachers' knowledge: PCK and GPK. Van Driel et al. (1998) conclude – regarding the study on primary school teachers' PCK – that it appears that familiarity with a specific topic, in combination with teaching experience, positively contributes to PCK. Moreover, GPK may constitute a supporting framework for the development of PCK (Van Driel et al., p. 681). Consequently, pre-service teachers and mentors working as experienced teachers are major groups in which to investigate PCK and GPK. Moreover, Nilsson and Loughran (2012) explore the development of primary science student teachers' PCK by focusing on experienced teachers, because beginning teachers' PCK tends to have little meaningful personal conceptualisation. For this reason, their study makes a significant contribution to the field of PCK in pre-service teacher education because it explores how PCK can be used to shape learning about (science) teaching.

6.1 Aim of the Study

This study aims to investigate the PCK and GPK of Finnish and Thai primary school teachers in the context of teaching about an electric circuit and concepts related to the circuit. Therefore, the aspects of PCK and GPK are introduced, as below. This introduction will be utilised in the development of an interview protocol for teachers. The main topics covered for the interview are presented in Table 11.

Table 11 Main Topics in the Interview Protocol

Main Interview Theme	Sub-interview Theme
Individual's background	Personal data
	Educational background
PCK	Teaching background
	Aims for learning
	Student thinking
	Student misconceptions
	Procedural knowledge
	Resources
	Classroom technique
	Purpose of content knowledge
	Evaluation of student learning of conceptual knowledge
	Representations of concepts
	Classroom management
GPK	Content management
	Conduct management
	Covenant management
	Instructional models
	Social family models
	Information-processing family models
	Personal family models
	Behavioural system family models
	Classroom communication
	Teacher–student interaction
	Student–student interaction
No interaction	

6.1.1 Pedagogical Content Knowledge

Many scholars have used PCK (Shulman, 1987) as a main organising concept in research on teachers' knowledge. Chick, Baker, Pham and Cheng (2006) emphasise student thinking, the understanding of procedural knowledge, knowledge of resources, aims for learning, classroom technique, the purpose of content knowledge and student understanding of conceptual knowledge as the essential elements of PCK. PCK is a special knowledge domain that distinguishes teachers from other subject specialists (Shulman, 1987; Carlsen, 1999). As such, PCK has paved the way for understanding the complex rela-

tionship between the content of a subject and the teaching of a subject by using specific teaching and evaluation methods. PCK is a synthesis of all knowledge needed for teaching and learning a certain topic (e.g., Grossman, 1990; Nilsson, 2008). For example, Duschl, Schweingruber, and Shouse (2005) linked teachers' PCK to student learning in science, and therefore, PCK is an important part of the knowledge base of a teacher. Several scholars (e.g., Gess-Newsome, 1999a) include the following areas in PCK: teaching and collaboration strategies; knowledge about student interest, motivation, and learning of conceptual and procedural knowledge and skills; knowledge of student thinking, misconceptions, and the cognitive and affective demands of tasks and activities; knowledge about resources available to support teaching and learning; and curriculum knowledge and aims for student learning. For example, Hashweh (2005) has defined PCK as:

The set or repertoire of private and personal content-specific general event-based as well as story-based pedagogical constructions that the experienced teacher has developed as result of the repeated planning and teaching of, and reflection on the teaching of, the most regularly taught topics. (p. 277)

In Europe, especially in Germany, France and the Nordic countries, including Finland, instead of PCK, the term 'didactics' or, more precisely, 'didactical transformation' (in German, *didaktische Transformation*) has been used to describe processes similar to those described in the discussion of PCK (Kansanen, 2002). For this study, the concept of PCK utilised by Chick, Baker, Pham and Cheng (2006) is selected. The PCK category emphasises student thinking, the understanding of procedural knowledge, knowledge of resources, aims for learning, classroom technique, the purpose of content knowledge and student understanding of conceptual knowledge. The definitions of all categories are presented in Table 12 below.

Table 12. Definition of PCK Categories (Chick, Baker, Pham, & Cheng, 2006)

PCK Category: Knowledge of...	Definition: A teacher ...
aims for learning	describes a goal for students' learning
student thinking	discusses or addresses students' ways of thinking about a concept or recognises typical levels of understanding
student's misconceptions	discusses or addresses the way to prevent student misconceptions about a concept
procedural knowledge	displays skills used for solving scientific problems
resources	discusses/uses the resources available to

	support teaching
classroom technique	discusses or uses generic classroom practices
purpose of content knowledge	discusses reasons for content being included in the curriculum or how it might be used
evaluation of student learning of conceptual knowledge	assesses student's understanding of a scientific concept
representations of concepts	discusses materials, pictures or diagrams used to introduce a scientific concept

6.1.2 General Pedagogical Knowledge

GPK is a central component of teacher knowledge (König & Blömeke, 2011). According to Shulman (1987, p. 8), GPK involves 'broad principles and strategies of classroom management and organisation that appear to transcend subject matter', as well as knowledge about learners and learning, assessment and educational contexts and purposes. Similarly, Grossman and Richert (1988) state that 'GPK includes knowledge of theories of learning and general principles of instruction, an understanding of the various philosophies of education, general knowledge about learners, and knowledge of the principles and techniques of classroom management' (p. 54). The GPK concept of Morine-Deshimer and Kent's (1999) is used for this sub-study. They divided GPK into three main categories as follows: the instructional model (teaching method), classroom management and classroom communication.

I. Classroom management is consistent in noting the general principles of teacher behaviour that promote student achievement. Classroom management focuses on three major components:

- Content management does not refer to skills peculiar to teaching a particular subject, but rather to those skills that cut across subjects and activities (Froyen & Iverson, 1999). Doyle stressed that the core of instructional management is gaining and maintaining student cooperation in learning activities (as cited in Froyen & Iverson, 1999). Content management occurs when teachers manage space, materials, equipment, the movement of people and lessons that are part of a curriculum or program of study.
- According to Iverson and Froyen (1999), conduct management refers to the set of procedural skills that teachers employ in their attempt to address and resolve discipline problems in the classroom. For example, when stu-

dents are disobedient in the classroom, a teacher uses certain methods to reinforce the students by giving rewards, admiration, blame etc. If a student has a severe problem, the teacher may contact the student's parents or guardians so as to cooperate in solving the problem.

- Covenant management stresses the classroom group as a social system that has its own features that teachers have to take into account when managing interpersonal relationships in the classroom.

The three aspects of classroom management, as mentioned above, are the main protocols for interviewing teachers.

II. Instructional methods and teaching methods or models are used as synonyms. Joyce and Weil (1996) have defined teaching models as follows:

A teaching model is a pattern or plan that can be used to shape a curriculum or course, select instructional materials, and guide a teacher's actions. Models are designed to attain specific goals. When a teacher identifies a goal, he or she selects a particular strategy designed to attain that goal.

According to Joyce and Weil (1996), the models of teaching have been grouped into four families that share orientations towards human beings and how they learn. These families emphasise different goals for teaching and learning, and different types of social interaction. The families are the social family, the information-processing family, the personal family and the behavioural systems family, along with the teaching method concept of Joyce, Calhoun and Hopkins (2002). These families overlap, and a single teaching method could have characteristics of several families. This classification of teaching methods is not especially designed for science education. However, primary teachers teach all primary-level school subjects and adopt ideas from the teaching of other subjects for use in science teaching. Therefore, the classification offers a broad view of all possible teaching methods/models for use in science education.

- The teaching models that belong to the social family emphasises the learning of social skills while learning content knowledge. Classroom management plays a key role in organising teaching and learning in the context of social family teaching models. Examples of such models include social inquiry, the laboratory method, role-playing and group investigation.
- The information-processing family of teaching models emphasises enhancing human beings' innate drive to make sense of the world by acquiring and organising data, generating solutions and developing concepts. Some models focus on providing the learner with the information, whereas some emphasise concept formation, and some generate creative thinking, such as scientific inquiry, concept attainment, inquiry training etc.

- The personal family of teaching models focuses on the unique character of each person and his or her struggle to develop as an integrated, confident and competent personality. Human beings are able to develop and achieve a sense of self-worth and personal harmony, e.g., nondirective teaching, self-actualisation etc.
- The behavioural system family of teaching models emphasises modifying the behaviour of human beings to allow them to respond to information about how successfully tasks are navigated, e.g., social learning, simulation and direct teaching.

The overall picture of the teaching models that are mentioned above make up the outline of this study in terms of how the teacher teaches the students in the classroom by analysing the classroom phenomenon, along with the concept of teaching models. When collecting data about teachers' teaching, this outline helps us to easily categorise and group all the data.

III. Classroom communication is the interactive language and responses that are exchanged between the students and the teacher. Hurt, Scott and McCroskey (1978, p. 3) mention that 'Communication is the crucial link between a knowledgeable teacher and a learning student'. Teaching and learning cannot occur without communication. The concept of Anderson and Garrison (1998) was adapted in this sub-study. There are three common types of classroom interaction. The term of interaction emphasises interaction between teacher and students through using words, discussing, explaining and asking during teaching time. Moreover, interaction also focuses on interaction between students through small group work activities, discussions in laboratory work and group project presentations. Moreover, two forms of communication – verbal and non-verbal communication (Johnson, 1999) – were applied to Anderson and Garrison's concept too. The three types of classroom communication are as follows:

- Teacher–student interaction: a teacher and student respond to one another or interact together through verbal or non-verbal responses, such as questioning, discussing, presenting, explaining, answering, complimenting, touching, facial expression and personal space during classroom teaching.
- Student–student interaction: students respond to one another or interact together through verbal and non-verbal responses, such as discussing, brainstorming, talking, writing, questioning, answering, touching and facial expression during classroom learning.
- No interaction: the teacher and students do not respond to one another or interact at all in the classroom, such as each student doing her/his own work during an exercise.

- These three types of classroom communication are the framework via which to handle study data easily when analysing it.

Figure 8 summarises the theoretical framework of this sub-study. This framework was used to plan the interview protocol and interpret the results.

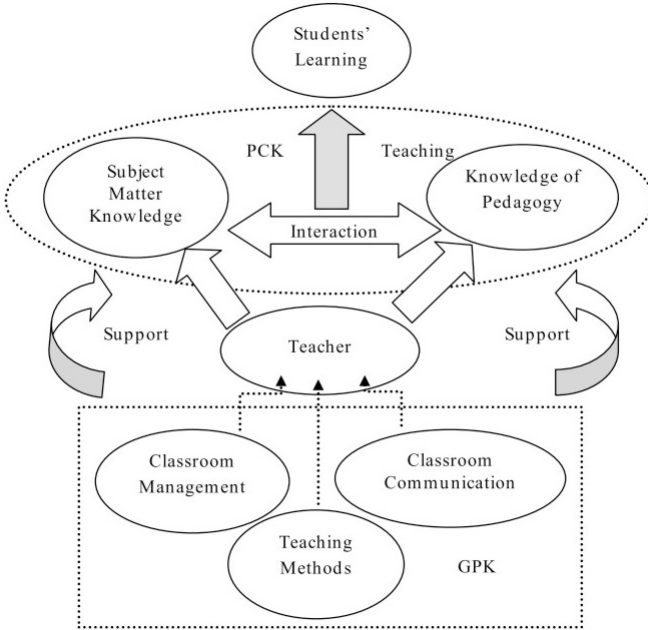


Figure 8. Theoretical framework summarising teachers' knowledge base.

Figure 8 also summarises the main theoretical views in my doctoral dissertation. The harmony of two theories on teacher knowledge (PCK and GPK) shows the knowledge a teacher employs in classroom teaching. According to the diagram, a teacher blends content knowledge and knowledge of pedagogy when teaching in the classroom. Shulman's PCK concept is topic- or concept-specific, and it explains how particular topics are taught to learners with diverse interests and abilities. Therefore, two kinds of knowledge interact while a teacher is planning a lesson to support the students' learning. From the point of view of a teacher, the question is as follows: How does a teacher transform his or her personal understanding of content knowledge into forms that are understandable for students? This thinking is called *pedagogical reasoning*. In classroom situations, the teacher is not always able to use only

PCK, because (s)he has to handle unexpected problems; therefore, GPK supports the teacher in the classroom through, e.g., classroom communication and conduct management (under classroom management).

6.2 Research Questions

As mentioned above, the purpose of this sub-study is to investigate the PCK and GPK used by primary school teachers while teaching science in Finland and in Thailand. The study questions that guided this study are:

- How do primary school teachers express their viewpoints on PCK and GPK while they plan or implement the electric circuit lesson at the primary level in both countries?
- How do Finnish and Thai primary school teachers' expressions of PCK and GPK differ in the context of the electric circuit lesson?

6.3 Methods

To answer the question, semi-structured interviews were conducted in this study. The interview protocol emphasised the concepts of PCK and GPK in the context of electric circuit teaching at the grade 6 level (see Appendix A).

6.3.1 Participants

There were six experienced primary school teachers, consisting of three Finnish primary school teachers in Helsinki and three Thai primary school teachers in Bangkok, who were interviewed for this study. The Finnish teachers were selected based on their schools' organising teaching practises: two from a university training school and one from a municipal school. Among the Thai participants, one Thai teacher was from an 'ordinary' comprehensive school and the others were from a demonstration (teacher training) school. All Finnish and Thai teachers were experienced teachers and had been or were working as mentor teachers in teacher education. Consequently, teachers were not 'ordinary', but had a strong background in education; it is plausible that they had reflected on teaching more than ordinary teachers had. 'Leading' or 'high-quality' primary school teachers were cases in this study and this reflected in their sense of idealism. As the curriculum (as a policy document) and textbooks (as a typical teaching material) are ideal for primary science, it was logically consistent to choose higher quality teachers as 'ideal teachers'. Therefore, this study compares a slightly more 'ideal' state regarding the current primary science situation in the two countries.

A mentor teacher teaches student teachers in addition to students in the classroom, or mentors the teachers regarding their practice teaching. Therefore, the outcomes of this case study offer information about what might be the optimal situation for teaching and learning in Finnish and Thai classrooms and situations in which student teachers have their practice teaching. The selection of the teachers could be called purposeful, which means that the informants were chosen for specific purposes to obtain rich data. This type of sampling selects information-rich cases for in-depth study. As one type of purposive sampling, the point of criterion sampling is to understand cases or individuals who meet a certain criterion, thereby providing rich data (Patton, 2002). The criteria for the selection of teachers were:

- 1) The teacher has recently taught or was teaching the electric circuit lesson at the grade 6 level.
- 2) The teacher was currently or has been a mentor teacher who has supervised student teachers during practice teaching.

According to the interviews, the personal-information results of the interviewees showed that all of the Finnish primary school teachers had a master's degree in pedagogy. In Thailand, two teachers had master's degrees in different majors: elementary education, and curriculum and educational supervision. One Thai teacher had a doctoral degree in educational research. There was one Finnish teacher who had 28 years of teaching experience. Meanwhile, one Finnish teacher and two Thai teachers had 25 years of teaching experience, another Thai teacher had 19 years and another Finnish teacher had 8 years. In addition to the teaching role, the primary school teachers from these two countries had other positions in the school; for example, one Finnish teacher had worked in an administration team, supervising student teachers at the same time. One Finnish teacher had participated in writing textbooks. In summary, all teachers were very experienced and educated. Therefore, this sub-study offers an optimal view of a primary teacher's PCK and GPK in the context of the electric circuit in Finland and in Thailand.

6.3.2 Interviews

Semi-structured interviews were conducted in Finland and in Thailand. There were several open-ended questions, which allowed the teachers to explain about their use of PCK and GPK in the planning and implementation of science teaching in the context of the electric circuit. An interview in the English language was prepared for the Finnish teachers. The participants were interviewed and the interviews were recorded with a tape recorder. The explanation of the interview procedure in both countries is described separately

because of the different regulations regarding how teachers should be contacted in Finland and in Thailand. In Thailand, before performing the interviews, permission letters (see Appendix B) from the thesis supervisor were sent to the principals, and they were asked for their permission to interview the teachers. Then, the interview appointment was agreed to. In Finland, the teacher connection was made directly, and the interview appointment was agreed to. The teachers were invited via email and three teachers responded voluntarily.

6.3.3 Interview situations

The average time for interviews was one hour per participant. All participants selected their classrooms as the place for the interviews. Firstly, I introduced myself and told them about my personal and educational background. Then, I began the interviews by asking them about personal information in order to relax them. The interview situations had a normal and comfortable atmosphere. At the beginning of the interview, the Finnish teachers were slightly nervous about using English, but during the interview, they relaxed. Then, I had to notice the participants' gestures and manner and use this information to ensure a good situation for both parties (interviewer and interviewees). Importantly, as a researcher, I avoided leading or suggestive questions. I let the teachers express their viewpoints freely based on the question aims and available time. To analyse the original expressions, I followed the steps below.

6.3.4 Interview data analysis

Firstly, all the teacher interviews were transcribed. The whole interview was considered as data for analysis. Therefore, the role of the interview questions was to be supportive of teachers' thinking. During the interview, teachers spoke about a certain issue during several of the questions that were asked. The interviews were analysed using inductive and deductive content analysis (Elo & Kyngäs, 2008).

The transliterated texts were read several times so as to ensure an accurate interpretation of the teachers' expressions. While reading them, notes and headings were written in the text in bold (see Appendices G and H). Then, the written text was read again to check that as many of the headings and notes that were written down in the margins were necessary to describe all aspects of PCK and GPK. Consequently, the lists of headings represented the analysis units (sub-categories) used in the inductive approach. After the analysis units (sub-categories) were analysed inductively, they were analysed

deductively based on the categories and sub-categories of PCK and GPK. Lastly, I counted how many times the teachers expressed ideas related to the sub-categories and the numbers were presented by country (see Tables 13 and 14).

6.4 Results

This study presents the interviews of six teachers in the context of teaching the electric circuit at the grade 6 level in Finland and in Thailand. The aim of the interview was to compare the viewpoints on PCK and GPK that teachers employ in reflecting on and planning the electric circuit topic at the elementary level in both countries. The teacher interview protocol consists of three parts: personal information and teachers' electric circuit-related PCK and GPK.

6.4.1 How do teachers employ pedagogical content knowledge in their teaching?

The results of the analysed expressions from the point of view of PCK are presented in Table 13. The frequencies show how many times those three teachers in Finland and Thailand described issues related to PCK in each PCK category. Each sub-category is based on the interviews and was created during the content analysis. The frequencies were quite close to one another in most sub-categories in the two countries.

Table 13. Frequencies of each PCK sub-category in the interviews of the teachers in Finland and Thailand

PCK Category: Knowledge of	Sub-categories (Analysis Units)	Frequency Expressions	
		Finland	Thailand
Pedagogy			
- aims for learning	Importance of electricity and its relationship to everyday life	1	3
	Understand how the electric circuit works	2	1
	Understand the important concepts related to the electric circuit	3	3
- student thinking	Ask questions/discuss and engage in hands-on activity in order to support thinking	15	10
	Use media (TV, Internet, movies) in order to support student thinking	3	-

- student's misconceptions	Support students in learning concepts through an activity	9	6
	Support students in learning concepts through the use of a textbook	6	-
- procedural knowledge	Students perform an experiment with authentic materials	9	11
	Students draw circuit diagrams	2	-
- resources	Authentic materials (wires, bulbs, batterie etc.)	3	7
	Computer materials (Internet, YouTube, Google etc.)	13	8
	Museum	1	-
	Publications (articles, textbooks etc.)	6	3
- classroom technique	Use several techniques depending on the situation	2	-
	Use a textbook and follow it with students	3	-
	Support every student in co-operating in class	6	6
Content			
- use of content knowledge to	Understand the concepts in order to apply them in everyday life	3	3
	Know how to save electricity	1	1
- evaluation of student learning of conceptual knowledge	Via test at the end of the lesson	2	3
	Checking students' homework or assignments	2	3
	Informal evaluation through listening to students' conclusions, discussions and presentations	4	8
- representations used for content	Picture	1	1
	Drawing	1	2
	Simulation	-	1
	Authentic materials	3	1
	Representation in the textbook	2	-

The teachers shared similar aims in terms of learning about the electric circuit and the concepts related to it, such as making simple couplings, concepts used for describing the electric circuit, saving of electricity and the use of electricity in everyday life. Direct quotations from the teachers support these conclusions:

After they learned this lesson, they got some kinds of skill to learn to solve some kind of problem in their everyday lives, for example... well, whatever ... the TV is not working also. If they would think that OK ... there is no electricity. What should I do? How do I probably fix it? Can I fix it myself? Should I plug it? And so on. (FT1)

I usually do [demonstrations] because it is very important to motivate them or talk about [concepts related to the electric circuit] ... we need the electricity. (FT2)

After they have learned, they will understand the reason why they have to learn about the electric circuit or electricity because it is close to our lives and we must know how to use it in a safe way. (TT2)

Scientific issues happen in everyday situations. I always take one of those situations relating to the lesson in my teaching. For example, the news talked about ... eer ... the solar cell. Then, I take this issue to the classroom for a discussion about how we save electricity. (TT3)

Moreover, all teachers enhanced the students' procedural knowledge through an experiment with authentic materials. Drawing a circuit diagram and symbols was used as one way to support the procedural knowledge of students in Finland.

Yes ... we have learned about the circuit diagram drawing and then ... errrrr ... there are all kinds of markings, and then, they have been open and closed-circuit ... then, they should do the connections like the picture is. (FT1)

The Finnish teachers stimulated student thinking by asking questions and using media. The frequencies in both of these sub-categories were higher than in Thailand. In contrast, the Thai teachers did not mention the use of media to stimulate student thinking at all.

Museums and publications, such as articles, books etc. were mentioned as information sources by the Finnish teachers to broaden student knowledge beyond the textbook. One Finnish teacher used the museum as one source for enhancing students' learning. Finnish Teacher 2 expressed it as:

I took the class to the museum of technology in Helsinki, and they have a special area about electricity, so we had an overall guided tour, and then, there was a paper sheet thing, and I said that this is about the electricity. You go through the exhibition and fill out the paper.

Moreover, computer materials were mostly referred to in both countries as other resources. About the representation of concepts, the electric circuit concept was introduced via the Finnish textbook as well as via authentic materials. In Thailand, the Thai teachers employed various ways of representing the concepts; that is, pictures, simulations, authentic materials and drawings.

Afterwards, I make a conclusion about what they have been doing, and then, after that, we might look at the textbook and give names to the concepts. You know, after work, we might look at the textbook and give them the concept. (FT3)

In the electric circuit lesson, I draw a picture by myself or sometimes use PowerPoint or a simulation to show students that if I cut this way from the picture, the light should be shut. (TT1)

If I need them to get the concept, I will use the complete picture, but I prefer the students to draw by themselves because they will practice their hand drawing at the same time. (TT2)

I review the knowledge of electrical symbols, such as bulbs, wires and batteries, with students via PowerPoint or a realistic figure. (TT3)

Regarding classroom technique, two Finnish teachers expressed how they used several techniques for instruction, depending on the situation in the classroom. For example, they made students ready and drew their attention through singing a song, telling a story and so on. One Finnish teacher followed the textbook with the students, while no Thai teachers mentioned the use of the textbook at all. Furthermore, the teachers from both countries proved the students' understanding of the conceptual knowledge via the students' conclusions, discussions and presentations in the classroom.

6.4.2 How do teachers employ general pedagogical knowledge in their teaching?

Table 14 presents the frequencies showing how many times those three teachers in Finland and Thailand described issues related to GPK in each GPK category. Each sub-category is based on the interviews and was created during the content analysis.

Table14. Frequencies of each GPK sub-category in the interviews with the teachers in Finland and Thailand

GPK Category		Sub-categories (Analysis Units)	Frequency: Number of Expressions	
Main	Sub		Finland	Thailand
1. Classroom management	1.1 Content management	Regard and follow the science curriculum	3	3
	- Curriculum	Content knowledge	5	4
	- Teaching preparation	Plan for teaching	5	6
	- Learning material	Textbook	6	3
		Blackboard	1	3

		Computer materials	13	10
		Authentic materials, such as bulbs, wires, batteries etc.	6	8
		Pictures	8	2
		Visualiser	3	-
	- Student arrangement	In small groups	11	13
		In pairs	6	-
	1.2 Conduct management			
	- Resolve discipline problem	Set the rules in the classroom	2	4
		Use a reinforcement approach	-	3
		Few discipline problems found	2	-
	1.3 Covenant management			
	- Interpersonal relationships among students	Work and discuss together in a small group	7	6
		Use nice words and be friendly with others	3	3
	- Relationship between teacher and students	Be nice, reasonable and friendly with students	1	1
		Help and encourage students when they have any kinds of problems	3	3
2. Instructional methods	- The social family model	Laboratory method/practical work and learning in a small group	11	13
	- The information-processing family model	Concept attainment and the use of a variety of resources to support the learning of concepts	19	2

	- The personal family model	Students must have scientific skills, such as being open-minded, curious, observant, wondering, able to think, ask and discuss, as well as having a problem-solving attitude	5	6
	- The behavioural systems family model	Teaching with the 'rules and reinforcement' approach in order to control the students' behaviour	3	7
3. Classroom communication	- Teacher–student	Read together, ask questions to the whole class, have students answer, engage in classroom discussion, have a teacher or student present to the whole class, have a teacher touch or smile at students	8	10
	- Student–student	Discuss in a small group, engage in practical work in a small group	10	17
	- No interaction	Students read the textbook and do homework exercises/assignments on their own	2	3

Table 14 presents the results for the analysed expressions from the point of view of GPK. It shows that overall, participants accepted the fact that the curriculum is important in their profession; they regarded and followed the science curriculum when planning the lessons. 'You have to... I think it [curriculum] controls our job and that we have to use it. I don't know, how do you say... kind of, well... it's kind of law. It has a static nature; being kind of... it's really... you have to follow it. You can't skip it' (FT2). Furthermore, all of the teachers recognised the content knowledge in their lesson plans in terms of surveying the overall contents of the lesson before beginning teaching that lesson and then considering the teaching method. The Finnish teachers expressed their ideas about learning materials: the textbook is always important to present the important concepts in the lesson, as well as computer materials (YouTube, webpages), authentic materials and pictures, which were also employed in electric circuit teaching. For Thai teachers, the first three

learning materials used in teaching were computer materials, authentic materials and the blackboard.

In addition, a minor difference was that Thai teachers always arranged students in small groups, while Finnish teachers organised students both in pairs and in small groups for electric circuit instruction.

Sometimes, they were sitting in pairs. Sometimes, they were sitting in small groups. (FT1)

They decided by themselves ... I quite often say to make groups from 1 to 4, In grade 6, I have 26 students, and if you try to have much hands-on teaching, it's almost impossible ... or in pairs ... I have 10 or 12, so they can work in pairs. (FT2)

I form students into groups of around 3–4 people in one group. The maximum is four. (FT3)

Referring to discipline problems in terms of the conduct management (a sub-category of GPK), in Finland, there were fewer discipline problems during teaching.

No ... no ... Actually, I have taught many classes during the eight years. I have never met a class that would have discipline problems after teaching them unlike, so I think it relates to the interaction ... between teacher and students, and the students want to act so that they please the teacher as they like the teacher and they respect the teacher. (FT1)

I really don't have any discipline problems because I believe that when I teach in the proper way ... when my methods are suitable ... eer ... when my methods are such that will interest or will motivate them into doing the lesson, they quite seldom have any discipline problems. (FT3)

In Thai classrooms, there were minor discipline problems, such as talking in class, walking in the class etc. Therefore, Thai teachers emphasised the rules used in the classroom to solve student discipline problems. When the problems occurred, most Thai teachers solved the problems by using the reinforcement approach. Thai Teacher 2, as an example, said, 'Student discipline is about the positive and negative reinforcement, such as group scores, compliments, rewards and giving stars'. All of the participants supported the relationships among students by letting them work together in pairs or in groups and provided students with the opportunity to discuss and solve problems.

The second GPK category was teaching methods. The frequencies showed that the two most used teaching models/methods in Finland belong to the information-processing family and the social family. According to the Finnish teachers, the textbook, computer materials and publications used in

teaching the electric circuit support the students' concept formation. Meanwhile, the Thai teachers used the teaching models/methods that belong to the behavioural system family in their teaching because of student discipline problems in the classroom. As Thai Teacher 1 said, 'I set the rules in the classroom or in the lab and explain their responsibilities in terms of taking care together or keeping things orderly in the lab'. However, the laboratory method and experiments performed as group work in the social family were the main model/method for both countries for electric circuit instruction. Students had to discover and solve the problems (e.g., electric circuit connections) together in pairs, in small groups or by themselves under the teacher's facilitation. In addition, both Finnish and Thai teachers emphasised the personal family of models in terms of students' use of scientific abilities and skills, such as their questioning ability, observation, being curious and using problem-solving skills.

Regarding the last category of GPK, classroom communication, the analysis of the interviews showed that all of the interviewed teachers had three types of communication approaches. Regarding teacher–student and student–student interaction, this means that the teacher and students cooperated in working with the electric circuit by discussing, asking questions, answering questions, working with ideas to solve scientific problems, listening to the different viewpoints together, expressing themselves facially (smiling, nodding or shaking the head) and touching one another. One Finnish teacher proposed an interesting idea about non-verbal communication:

I think non-verbal communication is very important. Although I think we are not supposed to touch pupils, I do if I know that the pupil that I'm going to touch will not dislike it, so I can be very close or far away if I know that this pupil doesn't want to be so close, and so on, but I think non-verbal communication is more important than verbal. (FT1)

Teachers in Finland and in Thailand emphasised versatile forms of interaction within their classrooms. One important interaction style is when students interact with other students in pairs or in small groups while discussing, sharing ideas, presenting work, smiling, laughing and touching.

Well, if I put them working in here, then I will choose their pairs so that I would think that it would be easy for them to discuss together, and also, if they are working in a small group, it's important there is no one dominating the discussion so that the silent ones will open their mouths about what they are thinking. (FT1)

It always depends on the situation, but in a way, I'm a traditional teacher, and in the sixth grade, I also think it's important that they learn to like... read in a book, and we sometimes go through the text together and talk about it. (FT2)

I aim to be among the students as much as I can. I aim to walk around, help them and encourage them, and yes, I also teach, but my moments of direct teaching are

quite short. Mainly, I see my role as that I help them to study. I help them to set their own goals. And I help them to reach their own goals. (FT3)

Actually, students do not dare to come or talk to me, but I try to use conversation, not beating. I sometimes express to students that I care about them and worry about them all the time. (TT3)

No interaction aspect was present when students worked on their own. ‘You know, after the experiment, we might look at the textbook and give them the concepts. Then, they might do some exercises from the book’, Finnish Teacher 3 noted. Similarly, Thai teacher 3 said ‘Students will have their own lab book. I don’t give them much homework. The lab book is sent at the end of lesson to ask what the concept of the day is. What concept does this lesson give you?’

6.5 Discussion

The main result of this sub-study was that the experienced Finnish and Thai primary school teachers’ expressions regarding PCK and GPK related to the ‘electric circuit’ could be considered to be rather similar. Five of six teachers had graduated from a master’s level program. A textbook was used to present the concepts to the students and to prevent student misconceptions. The social family of teaching models was a major model for teaching in both countries. Finnish teachers emphasised teaching models that belonged to the information-processing family. Teachers emphasised teacher–student and student–student interaction in their instruction. However, the Finnish teachers used questions to support student thinking and employed computers as resources to obtain more information on the electric circuit topic. All of the Thai teachers mainly used an experiment utilising authentic materials in the lab in supporting the students’ procedural knowledge. Drawings and pictures were used in teaching the concepts in the electric circuit topic. There were some discipline problems, especially in Thai classrooms, and, therefore, Thai teachers emphasised the behavioural system family of teaching models.

The main outcomes reflected the fact that the Finnish teachers viewed PCK in terms of student thinking, student misconceptions and the use of the textbook in representing the concepts when teaching the electric circuit. Referring to GPK, the Finnish teachers were rather flexible in their teaching in terms of the fact that there were no specific techniques to use in handling students; this depended on the situation at the time. There were no strict rules for student discipline in the classroom. For Thai teachers, their views on PCK emphasised students’ procedural knowledge. Students were taught via an experiment with authentic materials in the lab. The textbook was not used as

the main representation of the concepts taught. Rules were set regarding classroom tidiness. Although all of the teachers from the two countries emphasised different aspects of PCK and GPK based on several influencing factors in the countries concerned, this analysis showed that PCK and GPK were still fundamental forms of knowledge for the teaching profession.

The Finnish teachers mentioned that there were no specific techniques, but that the techniques used depended on the situation in the classroom. This may reflect the perspective of flexibility in the Finnish classroom. The adopted flexible accountability system also promotes the use of alternative strategies for raising student achievement in classrooms (Aho, Pitkänen, & Sahlberg, 2006, p. 9), and it has had a major positive impact on teaching and, hence, on student learning (Sahlberg, 2009, p. 26). Moreover, a plausible reason to support the idea of flexibility is well-trained teachers in primary school. It is well-known that the instruction in Finnish teacher education programs is arranged to reflect pedagogical principles that newly prepared teachers are expected to practice in their own classrooms, from basic to advanced practices. As a consequence of this strengthened professionalism in schools, Finnish teachers have considerable classroom independence in terms of selecting the most appropriate pedagogical methods. They can diagnose problems, apply evidence-based conclusions and use alternative solutions in their classrooms and schools (Sahlberg, 2007). In summary, all of these may call for flexibility in the Finnish classroom.

Secondly, referring to student discipline problems, the analysis found that there were fewer problems in the Finnish classrooms, while there were some in the Thai classrooms. Based on the idea of class size, at the primary level, the average class size is fewer than 20 students per classroom in Finland (OECD, 2012). In contrast, Wößmann's research (2003) finds that in Thailand, average class sizes are as high as 50 students per class. Consequently, the number of students in the classroom certainly affects to what degree the teacher can control the class, and how much time the teacher is able to spend focusing on individual students and their specific needs rather than on the group as a whole. Consequently, classroom size has an influence on student discipline problems in the classroom. Furthermore, the OECD undertook a survey on discipline in the classroom by interviewing students and found that 62 percent of students reported that the teacher 'never or hardly ever' or 'in some lessons' had to wait a long time for students to quieten down (OECD, 2011). 'In a typical classroom, students are likely to be walking around, rotating through workshops or gathering information, asking questions of their teacher, and working with other students in small groups' (Darling-Hammond, 2010). For this reason, the Finnish teachers may not recognise

students' talking and walking around in the classroom as being a major discipline problem during their instruction.

Thirdly, the analysis of teaching models (methods) revealed that both the Finnish and Thai teachers similarly emphasised laboratory methods and experiments for teaching the electric circuit. Hofstein and Lunetta (2003) have been performing research on laboratory use in science education for two decades. They still suggest that the science laboratory is central in our attempt to vary the learning environment in which students develop their understanding of scientific concepts, science inquiry skills and perceptions of science. Students can work cooperatively in small groups to investigate scientific phenomena. This emphasises the role of the social family of models. In addition, it can also reflect the personal family of models (teaching method) in terms of enhancing personal scientific skills. Another issue is that the Finnish teachers greatly emphasised conceptual instruction and textbook use. This outcome relates to the Finnish science textbook analysis, which found that Finnish textbooks emphasised conceptual knowledge (in Chapter 5). Thus, it is no wonder that Finnish teachers took conceptual instruction and the use of the textbook into account during their teaching.

Regarding teaching models (methods), the expressions of the participants showed the same results in terms of classroom communication. Two kinds of interaction – teacher–student and student–student – occur when applying the experimental/lab method in the classroom. For example, the participants began the electric circuit lesson by asking students some stimulating questions and then waiting for the students to answer. After that, the participants provided students with time to work in small groups to share ideas, discuss and learn together under the teachers' supervision. Lastly, the participants and students discussed the experimental results, asked questions and solved some problems that arose during the small group work as a whole class and then concluded with the important concepts for that day. According to the characteristics of teacher–student interaction, this interaction consists of the teacher asking questions with known answers, the students attempting to give the correct answer and the teacher evaluating the responses in terms of their consistency with the known answer. This is done to better understand the teacher's suggestions or requests, the students' replies and the teacher's evaluations. This method of communication conformed to the initiation–reply–evaluation (IRE) concept created by Mehan (1979). Therefore, all of the participants realised the importance of the teaching model (method) and classroom communication in terms of supporting student learning in science by selecting the proper method with which to instruct their students.

6.6 Conclusion

As mentioned above, the teacher should know how to facilitate students in learning a specific topic easily, how to build a congenial relationship with students and how to teach students well (and in what way this should be done). The sum of these minor details can gradually be shaped into the PCK and GPK of teachers. The highest quality of teaching will appear when the students study with happiness and curiosity. On the other hand, the teacher improves his/her teaching little by little by learning from the students in the everyday classroom context. As Morine-Deshimer and Kent (1999) suggested, students learn more when teachers use time efficiently, implement group and instructional strategies with high levels of involvement, communicate rules and expectations clearly and prevent problems by introducing a management system at the beginning of the school year.

As a conclusion to the present study, it will be challenging for both Finland and Thailand to apply the outcomes of this comparison. The comparison tells of differences between Finland and Thailand and, moreover, what is possible in science education. For example, the Thai primary school teachers may learn from Finnish teachers' practices how to avoid the discipline problems. However, the first priority for Thai education is classroom size reduction. Furthermore, the Finnish teachers may learn from the Thai teachers how to organise lab activities in relatively big classrooms and how to balance the learning of conceptual and procedural knowledge for students. We are planning to employ classroom observations and the stimulated recall technique along with the interview to learn more about the science-education practices in these two different countries.

7 Trustworthiness of the Research

This research report compares Finnish and Thai science education by analysing the science curricula, science textbooks and primary school teachers' ideas on PCK and GPK. The data were curriculum documents, textbooks and interview transliterations. All data were analysed via the content-analysis method. The research report is qualitative in nature. In the following section, the trustworthiness of the research is described. Qualitative research deals with finding answers to a social or human issue by drawing upon different perspectives. Such research has no firm truth; the findings depend largely on how or what individuals experience during that time (Denzin & Lincoln, 2005). The qualitative method is more subjective than the quantitative method. For this reason, qualitative research necessitates that the quality of the research is evaluated via its trustworthiness. Trustworthiness can be determined through credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985).

The traditional evaluation criteria for reliability and validity used for positivistic research do not fit well with the study design and the methods that were principally applied in this study. As Shenton (2004, p. 63) suggested, 'The trustworthiness of qualitative research generally is often questioned by positivists, perhaps because their concepts of validity and reliability cannot be addressed in the same way in naturalistic work'. The trustworthiness of qualitative research can be evaluated by a diverse range of criteria (Lincoln & Guba, 1985; Patton, 2002; Graneheim & Lundman, 2004). Guba's (1981) constructs correspond to the criteria employed by positivist investigators as follows:

- 1) Credibility is capable of being believed, believable or a credible statement.
- 2) Transferability is concerned with the extent to which the findings of one study can be applied to other situations or contexts (Merriam, 2002).
- 3) Dependability is concerned with consistent and repeated findings. If the work were repeated in the same context, with the same methods and with the same participants, similar results would be obtained.
- 4) Confirmability concerns a study's objectivity. The intrusion of the researcher's biases, motivation or interest should be eliminated; therefore, the findings are formed by the respondents and a degree of neutrality exists.

Moreover, Patton (2002) proposed that the quality of a study can be judged by its intended purpose, available resources and the procedures followed. As Graneheim and Lundman (2004, p. 9) stated, 'Research findings should be as trustworthy as possible and every research study must be evalu-

ated in relation to the procedures used to generate the finding'. Therefore, all criteria of trustworthiness as aforementioned are described in this report. Based on the content-analysis technique and the interview method used to collect the data, each criterion used is explained topic by topic below.

7.1 Credibility

Lincoln and Guba (1985) argued that ensuring credibility was one of the most important factors in establishing trustworthiness. The data analysis as one component of credibility has a two-step process that was taken into account: developing a coding scheme and developing a standard for coded data (Potter & Levine-Donnerstein, 1999). First, to validate that process in this research, the coding scheme development here refers to the analysis of national science curricula and the analysis of science textbooks; the coding schemes/units were deduced from several theories related to the study's purpose. The coding procedure was identified clearly, so that other coders may do the same (see the example in Section 6.3.4 Interview Data Analysis). Moreover, the coders shared common viewpoints and engaged in in-depth discussions during the development of the coding schemes. This all supports the validity of the study. As Graneheim and Lundman (2004, p. 110) stated, 'Credibility of research findings also deals with how well categories and themes cover data, that is, no relevant data have been inadvertently or systematically excluded or irrelevant data included'. Second, a standard for coded data refers to how well a coder concentrates and correctly codes the content. In this case, other coders (experts in science subjects) and I recorded the number of similar ideas in an interpersonal discussion, which can show that various researchers and experts would agree with the way those data were labelled and coded.

Other approaches to ensure credibility mentioned here are the analyst and methodological approaches. The analyst approach was used to verify the credibility in the national science curricula and science textbook studies. Although the coding schemes were not similar, the procedure and the context (primary science education) of these two studies were similar. More specifically, three researchers individually analysed the science curricula and the science textbooks at the same time. The advantage of having multiple analysts is to provide a check on data perceptions and to illuminate the blind spots in an interpretive analysis. The data analysis did not gain from consensus, but we need to understand other analysts' views of codifying data. Moreover, the methodological approach was followed for the study on primary school teachers' PCK and GPK. Data were not only collected from the interviews, but also from classroom observations and documentary investiga-

tion to see the congruence of findings using different methods. The interviewees were questioned about the classroom environment, classroom management, classroom routine etc. (the GPK aspect of the interviewed teachers); therefore, the researcher verified their viewpoints on GPK issues by observing classrooms as well. Classroom observation, in this case, means the classroom decoration, desk and chair organisation and the overall classroom environment. Several documents such as lesson plans, student books and student project work were presented by the interviewees as well. Three different methods of data collection confirmed the interview results quite well.

As noted, there were six participants in the interview study, raising concern about the reliability and validity of small samples. To address this concern, Ritchie, Lewis and Elam (2003) stated that samples for qualitative studies are generally much smaller than those used in quantitative studies (Ritchie, Lewis, & Elam, 2003). Moreover,

... there are no rules for sample size in qualitative inquiry. Sample size depends on what you want to know, the purpose of the inquiry, what's at stake, what will be useful, what will have credibility, and what can be done with available time and resources. (Patton, 2002, p. 244)

Consequently, interview-based studies involving as few as six participants have become common in social science research. Furthermore, one advantage of qualitative interviewing is that it can provide an understanding of things that cannot be directly observed, such as the feelings, thoughts, opinions, attitudes or behaviours of interviewees. Crouch and McKenzie (2006) researched the use of small samples in interview-based qualitative studies, arguing that a small number of cases (less than 20) will facilitate the researcher's close association on the respondents and enhance the validity of fine-grained, in-depth inquiry in naturalistic settings.

To ensure the study's credibility, the Thai science textbook was translated into English and proofed by others, as there is only a Thai version. The analysis was done precisely by the analysts based on the use of the English language as a second language. The Finnish science textbook is already in English, so there is no problem with its analysis. In fact, the science curricula of both countries have information in the English language. The iterative analyses of both the textbooks and curricula were carried out by the same analysts. For this reason, the science curricula and textbook information did not hinder credibility.

7.2 Transferability

Several scholars use the term transferability, while some use generalisability instead. Merriam (2002, p. 28) proposed that transferability 'is the extent to which the findings of one study can be applied to other situations, settings or groups'. However, transferability is possible when the researcher provides quite clear and distinct information on the culture and context, participant selection, data collection and analysis method used in his/her research. According to Zhang and Wildemuth (2009), transferability may not depend on the researcher providing suggestions about transferable results, but rather on his/her confidence that the datasets and descriptions are rich enough. Then, readers are able to make judgments about the findings' transferability to their own context.

In this research, three sub-studies were conducted in the form of a comparative study. All of the subjects were purposefully selected such as national science curricula, science textbooks and interviewed participants, under the Finnish and Thai contexts. Consequently, the description of culture and context was clear. In addition, the findings can be applied to other contexts and situations; the outcomes of the three sub-studies have already been reported to international audiences through international peer-reviewed journals and conference proceedings: two sub-studies have been published and one is under review. The referees and audience for these articles are from Asia and Europe. The acceptance of the articles is one sign of the acceptance and transferability of the sub-studies and the study as a whole.

7.3 Dependability

The dependability of the research could be increased by carefully planning the overall research procedure, including the methods used and decisions made throughout the process, the coherence of the internal process and the way in which the researcher accounts for changing conditions (Bradley, 1993). According to Stake (1995), the process should be reasonable and systematic to ensure that the data collection has yielded knowledge of interest and is in line with the purpose of the research.

First, the structure and the questions used in the semi-structured interviews were intentionally organised and tested in the study of teachers' PCK and GPK. The preliminary study on teachers' PCK and GPK took place a year beforehand to modify the original interview protocol and analysis procedures. The participants in the preliminary study did not participate in the main study. During the interview process, the researcher avoided leading or

suggestive questions (Herman & Bentley, 1993). Second, in the interview situations, especially when the participants had not heard of specific terms before or when they used the terms in their own language, the discussion and further information were taken into consideration at once without leading the interviewees to reply or interrupt their train of thought.

Finally, for the data analysis of science curricula and textbooks, two researchers and I individually analysed the same set of data: contents of the science curricula and the textbook chapters. After the analysis was completed, we compared the coding decisions and discussed the reliability of the coding. After agreeing on the coding scheme and analysing the data, we obtained 75% agreement on the analysis of the textbook text. In the analysis of curriculum texts, we decided to employ an iterative process. These procedures were followed to increase the reliability of the coding as it is described in the documents of the United States General Accounting Office (1996).

7.4 Confirmability

The issue of confirmability refers to ‘the extent to which the characteristics of the data, as posited by the researcher, can be confirmed by others who read or review the research results’ (Bradley, 1993, p. 437). To explain this issue, the influence of the researcher on the research procedure is very important, e.g. his or her motivations, biases and interests (Patton, 2002). In this research, researcher bias was not a significant threat because the main studies were conducted using content analysis. First, the coding scheme was mainly based on an extensive literature review rather than on the opinions of the researchers. For example, in the content analysis of textbooks, an international PISA Scientific Literature Framework was used as a coding scheme. Second, in all of the analyses, more than one researcher in addition to me analysed the data and consequently, agreement was reached. I, as the main researcher here, could not influence the findings or the other researchers. Furthermore, every step of the research procedure has already been reported in detail in each chapter describing the sub-studies, such as the criteria of case selection, coding process and data analysis method.

In addition, the interviews on the PCK and GPK of primary school teachers were carried out purposively and reported in detail. From this viewpoint, I, as the main researcher, recorded the interviews to prevent the research from being a narrative of my own opinions. Unacknowledged influences have been decreased by the theoretical knowledge influencing the overall data analysis procedure.

Finally, objectivity can be seen from the quantitative style used in reporting the data in this research report. Descriptive statistics were utilised to confirm the findings beyond the narrative description deriving from the content analysis. The quantitative style of reporting provides an objective measure of reality (Williams, 2007).

8 Discussion

This comparative research project emphasised the analysis of educational documents, e.g. national science curricula, science textbooks and teachers' PCK and GPK. The research questions were related to (a) the national science curricula; (b) the science textbooks analysed at the primary school level; (c) the knowledge primary school teachers employ while planning and implementing science lessons. Therefore, the aim of this comparative study was to compare results between nations. The similarities and differences in the results provide insight into primary science education at the primary level in both countries.

The research demonstrated that the content analysis of the science curricula, the science textbooks and primary school teachers' expressions of PCK and GPK provided information according to the aims, content, contexts and teaching methods used in primary science education. In addition, this comparative study demonstrated the importance of taking into account the cultural setting of each study.

In this chapter, the discussion is divided into four sections: a summary of the three sub-studies' main outcomes (Section 8.1), the research report's relevance (Section 8.2), the research implications (Section 8.3) and the need for further research (Section 8.4).

8.1 Main outcomes of the three sub-studies

My original interest in this research was my curiosity regarding the reasons for Finnish students' success on the PISA Scientific Literacy Assessment. In order to clarify the reasons, I engaged in a comparative study of primary science education in terms of the science curricula, science textbooks and primary school teachers' PCK and GPK in Finland and Thailand. The research report's theoretical framework (Chapter 2) was related to the main outcomes of the comparative study.

The main findings of the science curricula analysis revealed that the Thai curriculum was more similar than the Finnish curriculum to the PISA framework. The Thai curriculum emphasised the scientific process, and the Finnish curriculum, the concepts and contexts in which these concepts meet, rather than the process. Similar to the main outcomes of primary school teachers' interviews, the results showed that the Finnish teachers had flexibility in their teaching: they did not have specific techniques with which to handle students, and the techniques used depended on the situations occurring at the moment. Finnish teachers emphasised the teaching of concepts through textbook and

computer materials. In Thailand, teachers emphasised the teaching and learning of procedural knowledge, and consequently used experimentation, along with authentic materials in the lab. Finally, the science textbook analysis results showed that the Thai textbook emphasised procedural knowledge, while conceptual knowledge was more strongly emphasised in the Finnish textbook.

As mentioned above, I found coherence among the three sub-studies' results, indicating a combination of the following steps: the national science curricula (Step 1), the science textbooks (Step 2), and the primary school teachers' PCK and GPK (Step 3) in the four-step framework of the research (Chapter 2). I discussed a bit more about the national curriculum in Step 1. According to Mullis et al. (2009), the national level curriculum specifies the goal, purposes and immediate objectives to be accomplished. Other materials like textbooks are combined with the national curriculum to create the intended curriculum (or written curriculum). Dissimilarly, the implemented curriculum refers to the various learning activities or experiences of students within the school and classroom that are designed to implement the goals of the system—called the intended curricular outcomes. In this research, the achieved curriculum (or learned curriculum), which refers to the products of schooling such as knowledge, skills and attitudes that are actually learned, is not in the focus of the study.

Beginning with Finland, the science curricula as a master plan for teaching emphasised many concepts and contexts, and then the Finnish teachers expressed their ideas that they felt complemented the curriculum. For this reason, they mainly focused on the teaching of concepts through textbook and computer materials. As mentioned, Finnish science textbooks also emphasised conceptual knowledge for students' learning. This may reflect the fact that science education in Finland is bottom-up in its implementation of the four-step framework. In the Thai context, the scientific process and concepts were mainly highlighted at the first step in the Thai science curriculum. Therefore, Thai teachers implemented the curriculum by focusing more on procedural knowledge in their instruction than on conceptual knowledge. A plausible response as to why Thai teachers concentrated more on procedural knowledge than on conceptual knowledge is that they strove for students to primarily develop scientific skills. This is relevant to the analysis of science textbooks, as procedural knowledge was again recognised in science subject teaching. In conclusion, the curriculum, the teachers and the textbooks used in science education are the indicators of an education system's outcome. Figure 9 summarises the overall outcomes of the three studies.

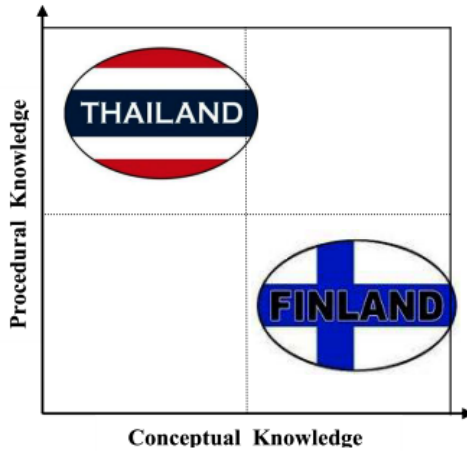


Figure 9. Summary of the main outcomes from the comparative study

8.2 The relevance of the research project

As Hantrais and Mangen (1996) suggested, for comparative research on two countries, the differences and similarities of both countries should be discussed in a cross-cultural context. There are several differences in the cultural settings of Thailand and Finland, such as their traditions, cultures, value systems, lifestyles, thought patterns, environments and languages. These factors influence the findings in a comparative research study, especially dissimilar results. Hence, cultures, value systems and environments as key influential factors found in this comparative study have been discussed from the point of view of the success of the Finnish education system.

The culture in a school refers to the manner in which the school is organised and students' learning is supported. Mitchell and Willower (1992, as cited in Horenczyk & Tatar, 2002) proposed the term organisational culture, which includes the norms and values of how people interact with others when they are approaching the goals of an organisation. Presumably, a strong organisational culture leads more readily to the attainment of an institution's goals. In Finland, essential to this culture is a culture of trust. 'The culture of trust simply means that education authorities and political leaders believe that teachers, together with principals, parents and their communities, know how to provide the best possible education for their children and youth' (Sahlberg, 2007, p. 157), or in other words, how goals can best be achieved. To be clearer regarding school and teacher autonomy in Finland, Lavonen (2008) stated that there are no inspectors, and there is no national evaluation of

learning materials or national assessment. For this reason, Finnish teachers are educated to be autonomous and reflective academic experts. An education system can be successful if teachers, a main factor in education, are autonomous and independent from authorities in their profession. Burriss (2012) wrote in his editorial in *Science* magazine that the most important part of any successful educational system is teachers who have independence from centralised authority and the time to prepare lessons and assess students' learning outcomes. The culture of trust in the Finnish education system is an important school culture characteristic and supports all actions in Finnish education. Consequently, Finnish teachers are professionals who play a key role in promoting citizens' quality of life and preparing citizens for the future.

The professionalism issue was also examined in the interview data of this research. All interviewed teachers were experienced teachers talking about their independence in planning and implementation of teaching. All of the Thai interviewees and one Finnish teacher prepared their lesson plans beforehand by following the science curricula as guidelines to help students reach the learning goals in the lesson. They wrote every lesson plan early in both formal and informal ways before teaching, and they followed the plans as they taught. Teachers are expected to set up the learning environment so students can learn. Materials, strategies and timing are planned for a lesson or rehearsal, whether formal or informal in nature. The lesson plan may help teachers realise their priorities in terms of lesson content and structure. Good lesson-planning skills are generally associated with good teaching (Brittin, 2005). In addition, Jacobs, Martin and Otieno (2008) conducted research focusing on in-service teachers' science lesson plans. They developed a science lesson plan analysis instrument for formative and summative programme evaluations of a teacher education programme. Participants were in-service teachers having 2–25 years of teaching experience. Jacobs et al. found that lesson plans influenced teachers in terms of helping them to teach in an orderly and organised way, which can reflect experienced teaching in this case. Moreover, their study implied the need for continued research in the area of teacher pedagogy like content planning and subsequent instruction.

In Thailand, schools lack autonomy, and many decisions are made at the local administrative organisation level not at the school or teacher level. A report analysing Thai school autonomy and schools' accountability policy (World Bank, 2012) described autonomy in the management of teachers as latent and highly centralised and regulated by civil service rules; as such, schools cannot select teachers and have no control over rewards or sanctions for addressing teacher incentives. The Thai curriculum offers more detailed

guidelines for teachers. *Matichon*, a local Thai newspaper, on 22nd January, 2013, presented six barriers facing Thai teachers. One was their lack of independence in instructional management. In addition, a significant reason school and teacher autonomy has been reduced is the establishment of the Office for National Education Standards and Quality Assessment (ONESQA). This organisation has the duties of developing criteria and methods for the external quality assessment of schools and educational institutions at every level. Through its outsourcing scheme, tens of private educational bodies under ONESQA supervision conduct external quality assessments for every institution at least once every five years (Nakornthap, n.d.). For this reason, rather than a trust culture in the Thai education system, there is a lack-or-trust culture in Thai educational administration.

In terms of the aims and values of education, equality is a crucial issue in the Finnish and Thai education systems. The interview results demonstrated that the Finnish teachers were able to accommodate students with different needs in their classrooms and have a more inclusive approach. The Finnish National Board of Education (FNBE) posits a special needs education approach that involves four phases: (a) instruction for pupils with sensory disabilities; (b) care for the disabled; (c) principle of normalisation and integration; (d) educational equality and equal educational services. This shows that equality in education plays an important role in Finland's education context. Thai teachers did not express their opinions on this issue, but equality in terms of special needs education is a first priority to be considered in the Thai education system as well.

In summary, the different cultures in Thailand and Finland reflect the norms and values guiding the organisation of their schools and education systems. The culture of trust was also found during the research project in many situations, specifically in Finland; for example, Finnish teachers were able to be contacted directly for interviews without asking permission from their school principals. This reflects teachers' independence in their job: they do what is useful for them or for others. The school principals trust the teachers and do not overly control them. Alternatively, the Thai participants were contacted by submitting permission letters to school principals and central administrators first, then waiting for their reply. Only after that was it possible to start the interviews.

Another issue from the research findings was that the science textbook analysis revealed that the Finnish textbook provides more detail, as indicated by the number of concepts it introduces. The number of concepts in the textbooks analysis and the interviewed teachers' comments on the conceptual knowledge related to the PCK aspect: pedagogy and content knowledge. For example, the Finnish teachers have always employed science textbooks for

conceptual instruction and took them into account as a major source of content knowledge in their teaching. The experienced teachers used their teaching experience as a lens for looking at the textbooks. Past teaching experience provided them with a sense of the topic and the pedagogical sequence for helping students to learn it. As the experienced teachers fit the textbooks into their curriculum scripts, they then moved back and forth between the two selections in ways that matched how they thought the topic should be taught (Schram, Feiman-Nemser, & Ball, 1990, p. 15).

An important influential factor related to education management is the environment. First, focusing on broad aspects of the environment in Finland and Thailand, e.g. weather, social infrastructure and population in the capital, these factors can make a difference in the countries' education management. For instance, in the capital of Thailand, there are 246,104 primary students (data from Ministry of Education, 2009), but in Finland, (including the capital) there are 152,613 students in the Uusimaa area (data from Finland, 2012). There are significantly more Thai primary students than Finnish students, which may result in a teacher-student ratio problem in Thai classrooms. The consequence of this huge number of Thai students also came up in the teacher interviews. In Thai classrooms, the interviewed teachers mentioned that there was an average of 40 students. Therefore, behavioural agreements were made in Thai classrooms. Moreover, the Thai teachers met behavioural difficulties and employed their GPK in those situations. On the other hand, Finnish teachers described being able to use more versatile teaching methods and rarely encountering behavioural difficulties in their classrooms.

The classroom environment can support students' learning. The physical classroom environment refers to the physical room in which the teacher and students are operating. It includes spatial elements (e.g. walls, ceiling, floor, windows) as well as classroom furnishings such as, but not limited to, chalkboards, desks, chairs, counters, work surfaces and computer equipment (Fisher, 2008). These topics were discussed with teachers during the PCK and GPK interviews. Teachers in Finland and Thailand took the classroom environment issues (e.g. related to the organisation of desks and chairs, classroom decoration, learning equipment) into account to support students' learning. The Finnish national-level curriculum analyses the learning environment as follows: 'The term "learning environment" refers to the entirety of the learning-related physical environment, psychological factors and social relationships' (FNBE, 2004, p. 8). This illustrates that the learning environment is an important aspect of supporting Finnish students' physical and emotional learning in the Finnish teaching-learning process. For Thai teachers, the national-level curriculum does not identify this issue specifically in the curricu-

lum. This can lead teachers to ignore the importance of the learning environment in their instruction.

As this research project has focused on three main components—curricula, textbooks and science education teachers in a primary school level context—outcomes from each separate component could be used to formulate a holistic view on the reasons for student success and failure in future international comparative studies. Many scholars have done research on a variety of topics related to curricula, textbooks and teachers. However, they have only mentioned one or two (not all three components) in their research (Johansson, 2006; NCCA, 2010; Remillard, 2005; Sun, Kulm, & Capraro, 2009). Prior related studies reflect the importance of all three components in educational research worldwide.

8.3 Implications

The first implication is regarding the framework used in the content analysis. It was interesting how the content of the two nations' documents in both textual and pictorial information reflect the ideas behind science education in the two countries. In order to do the content analysis study over two countries, an important issue was the selection of the analysis frameworks. The frameworks consist of concepts or theories that would be appropriate and neutral for cross-national comparison. For example, the sub-study of science curricula analyses was done in the PISA framework. Consequently, PISA could be one possible framework for doing content analyses of curricula.

The similarities and differences in primary science education in Finland and Thailand were analysed through the content analysis of the teachers' interviews, curriculum documents and textbook chapters. However, straightforward conclusions and implications should be drawn carefully, particularly strong statements on the failure or success of primary science education because of the variety of cultural differences in the two countries. In addition, the research findings provide an overview of similarities and differences in the two countries based on the different contextual and cultural perspectives, e.g. having a deeper understanding of some issues on primary science education, leading to new ideas or new perspectives on science education development. By doing a comparative study, we can learn something and gain insights from comparing research in different countries; for instance, some of the technical terms used in the studies have the same meaning, but use different words such as pedagogy, didactics, goals, aims and objectives. As Hantrais (1995) asserted, comparisons can lead to a deeper understanding of issues that are relevant in different countries and can lead to exciting insights. They may help to identify gaps in knowledge and point the researcher in a

new possible direction. They may also help to sharpen the focus of analysis of the subject under study by suggesting new perspectives.

The main outcome of this research is that it provided an opportunity to compare the science curricula, science textbooks and primary school teachers' ideas on a specific science lesson about electric circuits in two different countries. The results can guide educators, teachers, curriculum planners and principals to more develop curricula, textbooks and teachers' pedagogy as new tools for development. A plausible application is the development of teacher education. For example, some of the Finnish teachers' perspectives and ideas can be advantageous in teacher training programs in Thailand, such as how to prepare the physical and affective conditions before teaching, what kind of knowledge should be provided in teacher education programs and which content should be provided to teaching trainees. Thereby, both countries may learn and exchange useful educational information in the future. As Rothblatt and Wittrock (1993, p. 7) mentioned, comparison brings out contrasts as well as similarities, but it brings them out in relation to a problem, an event, a development, a change in direction or a stopping point for reflection.

8.4 Need for further research

There are several possibilities for widening and deepening our knowledge of why Finnish students are successful and Thai students are less successful on the PISA Scientific Literacy Assessment. In this thesis, those reasons have been explored by examining the curricula, textbooks and teachers' perspectives. These views are more or less 'input' views providing insight into possible circumstances for primary science education such as teaching methods, learning materials and classroom management. Teacher interviews offered information about teachers' knowledge base they could employ in a classroom situation. The analysis of curricula provided information on the aims and main concepts of primary science education in both countries. The analysis of textbooks highlighted significantly interpretations of the curricula. In these three analyses, there are several limitations, including the small number of teachers who were interviewed and the focus on electric circuits in the interviews and textbook analysis. Therefore, it will be more useful for the educational field if future researchers employ larger sample sizes of teachers and analyse a wider range of topics.

In this discussion section, the comparison of Finnish and Thai primary science education was rather general. This comparison would be stronger if the general education policy documents were analysed and compared. There-

fore, one avenue for future comparative research between Finnish and Thai primary science education could be to analyse the content in general curriculum and other education policy documents (e.g. Simola, 2005) and to combine this analysis with the analysis done in this thesis. The main advantage of doing this could be to further develop the education system, e.g. curriculum reform, teacher education development and school development.

The second avenue to acquire novel comparative research data on Finnish and Thai primary science education is to conduct research inside science classrooms. For example, classroom observation instruments, video recordings or questionnaires could be used to measure teacher factors such as classroom behaviours or pedagogical content knowledge (PCK) (Teddle & Reynolds, 2000). Through combining these data with students' learning outcomes, it could be possible to look for correlations between teacher behaviours, beliefs or other teacher factors and student learning outcomes (Wright, Horn, & Sanders, 1997; Muijs, 2006).

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Appendices

Appendix A

Teacher Interview Protocol

I appreciate you letting me observe your class. I have some questions I'd like to ask you related to the classroom lesson and some general questions. Would you mind if I taped the interview? It will help me stay focused on our conversation, and it will ensure I have an accurate record of what we discussed.

A. Personal Information

1. How long have you been teaching in this school?
2. What is your highest degree achieved? What was your major?
3. In what grade do you teach now?
4. Do you have another position besides your teaching role?
5. Have you ever received any awards for teaching?

B. Pedagogical Content Knowledge

6. Please describe how do you start teaching the electric circuit? Do you stimulate learning through activity or through listening to a lecture?
7. You always follow the textbook to teach the students? Do you use other methods?
8. How do you support student thinking through teaching about the electric circuit?
9. How do you teach them to learn about the electric circuit connection? In what way?
10. In your opinion, what are the main aims for students when learning about electricity?
11. What is your classroom technique to easily teach the electric circuit to the students?
12. From your point of view, what is the main reason for students to learn the content or concepts regarding the electric circuit?
13. How do you teach the concepts? How do you prevent student misconceptions?
14. How do you know that students understand the idea or concepts you teach? In what way?
15. What other resources will you recommend to the students in order to learn about electricity? Newspapers, museums, the Internet?

C. General Pedagogical Knowledge

16. In your opinion, is the science curriculum important for your career? How?

17. What do you need the students to learn about science? Is it the right concept, good characteristics, scientific skills, or all of these together?

18. What is the most important thing in your teaching?

19. When you teach the students about the electric circuit, how do you organize the students? Do they work in small groups, in pairs, or individually?

20. What about learning materials besides textbooks? Do you use anything else in your teaching?

21. How do you manage student discipline problems?

22. What is the relationship between you and students? And among the students?

Appendix B

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เรื่อง ขออนุญาตสัมภาษณ์ครูเพื่อทำวิทยานิพนธ์ในระดับปริญญาเอก
เรียน ผู้บริหารโรงเรียนอัสสัมชัญ แผนกประถม
สิ่งที่แนบมาด้วย จดหมายขออนุญาตสัมภาษณ์จากอาจารย์ที่ปรึกษาที่มหาวิทยาลัยเฮลซิงกิ
ฟินแลนด์

ด้วยดิฉัน นางสาว ภาวิณี ไสธายะเพชร นักศึกษาปริญญาเอก มหาวิทยาลัยเฮลซิงกิ ประเทศฟินแลนด์ ได้รับทุนจากสำนักงานคณะกรรมการการอุดมศึกษา (สกอ.) เมื่อปีพ.ศ. 2551 เพื่อศึกษาต่อด้านหลักสูตรและการสอนทางด้านวิชาวิทยาศาสตร์ในระดับประถมศึกษา และเมื่อสำเร็จการศึกษาแล้วจะกลับมาใช้ทุนที่คณะครุศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย สาขาวิชา ประถมศึกษา โดยในขณะนี้ได้ทำวิทยานิพนธ์ในหัวข้อเรื่อง “ความรู้ด้านเนื้อหาการสอนของ ครูวิทยาศาสตร์ระดับชั้นประถมศึกษาปีที่ 6 ในการสอนบทเรียนเรื่องไฟฟ้า”

จึงเรียนมาเพื่อขออนุญาตสัมภาษณ์คุณครูวิทยาศาสตร์ระดับชั้นประถมศึกษาปีที่ 6 ของ โรงเรียนจำนวนสองท่าน ผู้ซึ่งมีประสบการณ์การสอนเกิน 5 ปีขึ้นไป จักขอบพระคุณเป็นอย่างยิ่ง

ขอแสดงความนับถือ

(นางสาว ภาวิณี ไสธายะเพชร)

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เรื่อง ขออนุญาตสัมภาษณ์ครูเพื่อทำวิทยานิพนธ์ในระดับปริญญาเอก
เรียน ผู้อำนวยการโรงเรียนพญาไท
สิ่งที่แนบมาด้วย จดหมายขออนุญาตสัมภาษณ์จากอาจารย์ที่ปรึกษาที่มหาวิทยาลัยเฮลซิงกิ
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ด้วยดิฉัน นางสาว ภาวิณี ไสธายะเพชร นักศึกษาปริญญาเอก มหาวิทยาลัยเฮลซิงกิ ประเทศฟินแลนด์ ได้รับทุนจากสำนักงานคณะกรรมการการอุดมศึกษา (สกอ.) เมื่อปีพ.ศ. 2551 เพื่อศึกษาต่อด้านหลักสูตรและการสอนทางด้านวิชาวิทยาศาสตร์ในระดับประถมศึกษา และเมื่อสำเร็จการศึกษาแล้วจะกลับมาใช้ทุนที่คณะครุศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย สาขาวิชาประถมศึกษา โดยในขณะนี้ได้ทำวิทยานิพนธ์ในหัวข้อเรื่อง "ความรู้ด้านเนื้อหาการสอนของครูวิทยาศาสตร์ระดับชั้นประถมศึกษาปีที่ 6 ในการสอนบทเรียนเรื่องไฟฟ้า"

จึงเรียนมาเพื่อขออนุญาตสัมภาษณ์คุณครูวิทยาศาสตร์ระดับชั้นประถมศึกษาปีที่ 6 ของโรงเรียน ผู้ซึ่งมีประสบการณ์การสอนเกิน 5 ปีขึ้นไป จักขอบพระคุณเป็นอย่างยิ่ง

ขอแสดงความนับถือ

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เรียน ผู้อำนวยการโรงเรียนสาธิตจุฬาลงกรณ์มหาวิทยาลัย ฝ่ายประถม
สิ่งที่แนบมาด้วย จดหมายขออนุญาตสัมภาษณ์จากอาจารย์ที่ปรึกษาที่มหาวิทยาลัยเฮลซิงกิ
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ด้วยดิฉัน นางสาว ภาวิณี ไสธายะเพชร นักศึกษาปริญญาเอก มหาวิทยาลัยเฮลซิงกิ
ประเทศฟินแลนด์ ได้รับทุนจากสำนักงานคณะกรรมการการอุดมศึกษา (สกอ.) เมื่อปีพ.ศ. 2551
เพื่อศึกษาต่อด้านหลักสูตรและการสอนทางด้านวิชาวิทยาศาสตร์ในระดับประถมศึกษา และเมื่อ
สำเร็จการศึกษาแล้วจะกลับมาใช้ทุนที่คณะครุศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย สาขาวิชา
ประถมศึกษา โดยในขณะนี้ได้ทำวิทยานิพนธ์ในหัวข้อเรื่อง **"ความรู้ด้านเนื้อหาการสอนของ
ครูวิทยาศาสตร์ระดับชั้นประถมศึกษาปีที่ 6 ในการสอนบทเรียนเรื่องไฟฟ้า"**

จึงเรียนมาเพื่อขออนุญาตสัมภาษณ์อาจารย์ จักขอบพระคุณเป็นอย่างยิ่ง

ขอแสดงความนับถือ

(นางสาว ภาวิณี ไสธายะเพชร)

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Appendix C

Example of Finnish science curriculum analysis table

Subject	Textual information	Content knowledge of science:	Content knowledge about science:	Competence	Context
		1 physical systems, 2 living systems, 3 earth and space systems, 4 technology systems	1 nature of scientific inquiry 2 nature of scientific explanations	1 identify scientific issues (observe, include plan an inquiry; 2 draw evidence-based conclusions 3 explain scientific phenomena (use knowledge)	1 health, 2 natural resources, 3 environmental quality, 4 hazards 5 frontiers of science and technology
Environmental and natural studies	Environmental and natural studies is an integrated subject group comprising the fields of biology, geography, physics, chemistry, and health education. Instruction in the subject group includes the perspective of <u>sustainable development</u> .	not related to a category	not related to a category	not related to a category	environmental quality
Environ. & natural studies	The objective of instruction is that the pupils get to <u>know and understand nature and the built environment</u> , themselves and other people, human diversity,	not related to a category	not related to a category	identify scientific issues	not assigned to a category
Environ. & natural studies	and <u>health</u> and disease	not related to a category	not related to a category	not related to a category	health

Environ. & natural studies	Instruction in environmental and natural studies relies on an <u>investigative</u> , problem-centred approach in which the starting points are the pupils' existing knowledge, skills, and experiences; and things, phenomena, and events	not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
Environ. & natural studies	connected to the pupils' <u>environment</u> and the <u>pupils</u> themselves	not related to a category	not related to a category	not related to a category	environmental quality
Environ. & natural studies	With the aid of <u>experiential instruction</u> , the pupil develops a positive relationship with nature and the environment.	not related to a category	not related to a category	identify scientific issues	environmental quality
Environ. & natural studies	The contents of, and approaches used in, environmental and natural studies are selected on the basis of the pupils' prerequisites and developmental level, in such a way that studies can also be done as field work. Concepts associated with environmental and natural studies may be organized as modules in which the	not related to a category	nature of scientific inquiry	not related to a category	environmental quality

surrounding world, the pupils, and their actions as members of a community are examined.

		not related to a category	nature of scientific explanations	not related to a category	environmental quality
Environ. & natural studies	Studying these modules helps the pupils <u>understand their own environment and the interaction</u> between the individual and the environment.	not related to a category	not related to a category	not related to a category	environmental quality
Environ. & natural studies	learn to <u>act safely</u> , so as to protect themselves in their environment,	not related to a category	not related to a category	not related to a category	health
Environ. & natural studies	and to <u>follow instructions at school, in the immediate environment, and in traffic</u>	not related to a category	not related to a category	not related to a category	health
Environ. & natural studies	get <u>to know the natural and built environments in their neighbourhood.</u>	not related to a category	not related to a category	explain scientific phenomena	Environ-mental quality
Environ. & natural studies	to <u>observe the changes happening therein</u> , and to perceive their home region as a part of Finland and the Nordic countries	not related to a category	not related to a category	identify scientific issues	not related to a category
Environ. & natural studies	learn to <u>obtain information about nature and the environment by observing.</u>	not related to a category	not related to a category	draw evidence-based conclusions	Natural resources

Environ. & natural studies	<u>investigating</u> , and using a variety of source materials	not related to a category	not related to a category	identify scientific issues	not related to a category
Environ. & natural studies	<u>learn to make observations using the different senses and</u> simple research tools, and to <u>describe, compare, and classify their observations</u>	not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
Environ. & natural studies	learn to <u>perform simple scientific experiments</u>	not related to a category	not related to a category	draw evidence-based conclusions	not related to a category
Environ. & natural studies	Geography	not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
Environ. & natural studies	learn to <u>represent information about the environment and its phenomena</u> by different means	not related to a category	not related to a category	not related to a category	not related to a category
Environ. & natural studies	<u>learn to use the concepts by which the environment and the phenomena and subjects embraced by those concepts are described and explained</u>	not related to a category	not related to a category	draw evidence-based conclusions	not related to a category
Environ. & natural studies	<u>learn to use the concepts by which the environment and the phenomena and subjects embraced by those concepts are described and explained</u>	not related to a category	not related to a category	explain scientific phenomena	not related to a category

Appendix D

Example of Thai science curriculum analysis table

Subject	Textual information	Content knowledge of science:	Content knowledge about science:	Competence	Context
		1 Physical systems (chemical) systems,	1 nature of scientific inquiry	1 identify scientific issues (observe, include plan an inquiry;	1 health, 2 natural resources,
		2 living systems,	2 nature of scientific explanations	2 draw evidence-based conclusions	3 environmental quality,
		3 earth and space systems,		3 explain scientific phenomena (use knowledge)	4 hazards
		4 technology systems			5 frontiers of science and technology
Science	Science plays an important role in our present and future world communities, as it concerns all of us in our <u>daily lives</u> and livelihoods.	Physical systems	not related to a category	not related to a category	Health
		living systems	not related to a category	not related to a category	environmental quality
	Science also involves <u>technologies, instruments, devices</u> and various products at our disposal, which facilitate our life and work. All these benefit from our <u>scientific knowledge, which is combined with creativity</u> as well as other disciplines.	technology systems	not related to a category	not related to a category	frontiers of science and technology
		not related to a category	nature of scientific inquiry	not related to a category	not related to a category

Science enables us to develop our thinking skills in various respects— <u>logical, creative, analytical and critical.</u>	not related to a category	nature of scientific explanations	not related to a category	not related to a category
It also enables us to <u>acquire essential investigative skills</u> for seeking knowledge and <u>allows the ability for systematic problem-solving</u> , and for verifiable decision-making based on diverse data and <u>evidences.</u>	not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
Science is essential to the <u>modern world</u> , which is intrinsically a knowledge society.	technology systems	nature of scientific explanations	explain scientific phenomena	not related to a category
All of us therefore need to be provided with scientific knowledge so as <u>acquire knowledge and understanding of nature</u>	not related to a category	nature of scientific inquiry	explain scientific phenomena	natural resources
and <u>man-made technologies</u> that can be applied through logical, creative and moral approaches.	technology systems	nature of scientific explanations	explain scientific phenomena	frontiers of science and technology

	The learning area of science is <u>aimed at enabling learners to learn this subject with emphasis on <u>linking knowledge with processes</u>, acquiring essential skills for investigation, building knowledge through <u>investigative processes</u>, seeking knowledge and <u>solving various problems</u>. Learners are allowed to participate in all stages of learning, with activities organized through diverse <u>practical work suitable to their levels</u>. The main content areas are prescribed as follows:</u>	not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
		not related to a category	nature of scientific inquiry	identify scientific issues	not related to a category
		not related to a category	nature of scientific explanations	explain scientific phenomena	not related to a category
		not related to a category	not related to a category	identify scientific issues	not related to a category
Science	Living Things	living systems	not related to a category	not related to a category	natural resources
Science	and Processes of Life:	living systems	not related to a category	not related to a category	not related to a category
Science	basic units of living things;	living systems	not related to a category	not related to a category	not related to a category
Science	structures and functions of various systems	living systems	not related to a category	not related to a category	not related to a category

	of living things and processes of life;				
Science	biodiversity;	living systems	not related to a category	not related to a category	environmental quality
Science	genetic transmission;	living systems	not related to a category	not related to a category	Health
Science	functioning of various systems of living things, evolution	living systems	not related to a category	not related to a category	not related to a category
Science	and diversity of living things	living systems	not related to a category	not related to a category	natural resources
Science	and biotechnology	technology systems	not related to a category	not related to a category	frontiers of science and technology
Science	Life and the Environment:	living systems	not related to a category	not related to a category	environmental quality
Science	diverse living things in the environment;	living systems	not related to a category	not related to a category	natural resources
Science	relationship between living things and the environment;	living systems	not related to a category	not related to a category	environmental quality
Science	relationships among living things in the ecosystem;	living systems	not related to a category	not related to a category	environmental quality
Science	importance of natural resources, and <u>utilization</u> and management of <u>natural resources</u> at local, national and global levels;	living systems	not related to a category	explain scientific phenomena	natural resources
		technology systems	not related to a category	not related to a category	natural resources
Science	factors affecting	living systems	not related to a	not related to a	environ-

survival of living
things in
various environ-
ments

category

category

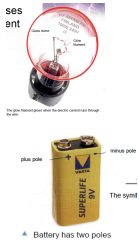
mental
quality

Appendix E

Example of Finnish textbook analysis table

Information in the textbook	Concept based on Physics terminology	Type of knowledge	How the concepts are introduced	Representation	Use of concept in context
Flash of lightning and the glow of a light bulb are similar phenomena. What causes them?	light bulb	Conceptual	Text	Analogy	STS
Electric current makes the glow filament glow	Electric current filament	Conceptual	Text Text	relation just used	Ideal Tech.app
The turning on of the light bulb in a flashlight can be compared to a flash of lightning. The condition for lightning to occur is that between the bottom of the thundercloud and the surface of the earth there are different types of electric charges	light bulb Electric charges	conceptual	text Text	analogy just used	tech applic sts
When a light bulb is connected with two wires to a battery , an electric current runs through the glow filament of the light bulb and the light bulb lights up.	light bulb wire battery Electric current	conceptual	relation relation relation relation relation	text text Text text text	tech applic tech applic tech applic ideal tech.app
The unit of voltage is volt (1V) and the unit of electric current is ampere	voltage volt electric current ampere voltage volt	Conceptual	introd. earlier relation itrod earlier relation intod earlier relation	Text Text Text Text Text Text	Ideal ideal ideal ideal historical historical

(1 A). The unit of the **voltage, volt**, is named after an Italian Alessandro Volta. He built the first **batteries** as early as 1800.



battery
just used
Text
historical

Electric current
light bulb
filament
Electric current
light bulb
filament
Manipulated fig.
Manipulated fig.
Manipulated fig.
text
text
text

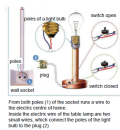
Battery
plus pole
minus pole
battery
pole
relation
relation
relation
relation

There is **voltage** between the **poles** of a **battery** and between the **poles** of an **accumulator**

Voltage
pole
battery
accumulator
Conceptual
relation
Text
Text
Text
Text
ideal
tech app
tech app
tech app
tech app

Small accumulators are the same size as normal batteries. **They** can be re-charged with a battery charger that is connected to a **socket**. So the **accumulator** can be used for a long time as long as you remember to charge it every once in a while.


Accumulators
Accumulators
socket
accumulators
analogy
relation
just used
relation
Text
text
text
text
tech app
tech app
tech app
STS



lamp	relation	analytical	tech app
switch	relation	analytical	tech app
wire	relation	analytical	tech app
socket	relation	analytical	tech app
plug	relation	analytical	tech app
pole	relation	analytical	tech app
lamp	relation	text	tech app
switch	relation	text	tech app
wire	relation	text	tech app
socket	relation	text	tech app
plug	relation	text	tech app
pole	relation	text	

Appendix F

Example of Thai textbook analysis table

Information in the textbook	Concept based on Physics terminology	Type of knowledge	How the concepts are introduced	Representation	Use of concept in context
In an experiment of electric devices connection e.g. wires, lamps, batteries , and other materials for checking they are resistors and conductors or not? The results of experiment are....	electric devices wires lamps batteries resistors conductors	Procedural	just used	Text	STS
	Conductors	Conceptual	Example	Line drawing	STS
	Resistors Resistors	Conceptual	Relation	Text	STS
Materials which have the electric resistable feature called resistors . The electric current cannot run through the circuit.					
You already know the element of electric circuit , now we should know about the electric devices and writing of their symbols	Electric circuit Electric devices	Conceptual	Relation	Text	Tech app
	battery	conceptual	relation	realistic	Tech app
	light bulb	conceptual	just used	realistic	Tech app
	wire	conceptual	relation	realistic	Tech app
	switch	conceptual	relation	realistic	Tech app
	motor**	conceptual	just used	realistic	Tech app
	electric bell**	conceptual	just used	realistic	Tech app

When we connect	battery	procedural	relation	text	tech.app
the battery, wire,	wire	procedural	relation	text	tech.app
and lamp making the	lamp	procedural	relation	text	tech.app
lamp glows. It	electric current	conceptual	relation	text	ideal
means that there is	electric current	conceptual	relation	text	ideal
an electric current	plus pole	conceptual	just used	text	tech.app
runs on. By electric	battery	conceptual	relation	text	tech.app
current runs from a	switch	conceptual	relation	text	tech.app
plus pole of battery	lamp	conceptual	relation	text	tech.app
through the switch	minus pole	conceptual	just used	text	tech.app
and lamp to a minus	battery	conceptual	relation	text	tech.app
pole of battery . It's	closed circuit	conceptual	just used	text	STS
called closed circuit .	lamp	conceptual	relation	text	tech.app
On the contrary, if	open circuit	conceptual	just used	text	STS
we connect incom-	battery	conceptual	relation	text	tech.app
pletely and the lamp	wire	conceptual	relation	text	tech.app
doesn't glow. It's	lamp	conceptual	relation	text	tech.app
called open circuit .	electric circuit	conceptual	relation	text	STS
Therefore, the	switch	conceptual	relation	text	tech.app
battery, wire, and	electric circuit	conceptual	relation	text	STS
lamp are the main					
elements of simple					
electric circuit . The					
switch functions as					
cutting and connect-					
ing the circuit .					
Batteries are cou-	batteries	Procedural	Relation	Text	tech.app
pled in series so the	in series	Conceptual	Relation	Text	STS
plus pole of the first	plus pole	Procedural	Relation	Text	tech.app
battery is connected	battery	Conceptual	Relation	Text	tech.app
with a wire to the	wire	Conceptual	Relation	Text	tech.app
minus pole of the	minus pole	Procedural	Relation	Text	tech.app
second battery and	battery	Conceptual	Relation	Text	tech.app
then connect to the	lamp	Conceptual	Relation	Text	tech.app
lamp . The voltage of	voltage	Conceptual	Relation	Text	Ideal
batteries coupled in	batteries	Conceptual	Relation	Text	tech.app
series is bigger than	in series	Conceptual	Relation	Text	STS
the voltage of one	voltage	Conceptual	Relation	Text	Ideal
battery . The use of	battery	Conceptual	Relation	Text	tech.app
battery will be	battery	Conceptual	Relation	Text	tech.app
longer.					

Appendix G

Examples of the original expressions and the bold texts showing the deductive analysis units based on the PCK categories and sub-categories

PCK category: Knowledge of	Examples of original expressions	
Pedagogy		
	aims for learning	
	Fin	Of course, they learn to understand how the system works . The system works to helps them to use electrical equipments in a safe way . (FT3)
	Thai	After they learn, they will understand the reason why they have to learn about the electric circuit or electricity: because it is close to our lives to use it, and we must use it in a safe way. (TT2)
student thinking	Fin	I think mainly, asking questions ...why? I encourage them by asking questions and asking them to tell me what happens? (FT3)
	Thai	Firstly, I always stimulate them by asking questions . Why is it like that? What happens next? What happens if we do like this? (TT1)
student's misconceptions	Fin	You know, after the experiment, we might look at the textbook and give them the concepts . (FT3)
	Thai	Students need to conclude the daily concept together in the classroom after the experiment. We discuss and check their conclusions group by group . (TT3)
procedural knowledge	Fin	Yes...we have learned about the circuit diagram drawing and then...errrrr...there are all kinds of markings... (FT1)
	Thai	I let them work in a group and experiment with the authentic materials . (TT2)
resources	Fin	We use quite a lot of Internet resources, but I have always told them that when they use the Internet , they should be very careful because there are might be some incorrect information.
	Thai	I extend their knowledge by telling them to search Internet, such by using as Google, YouTube ...for more information that they are interested in. (TT1)
classroom technique	Fin	It always depends on the situation , but in a way, I'm a traditional teacher, and in the sixth grade, I also think it's

	Fin	important that they learn to like <i>read in a book</i> , and we sometimes we go through <i>the text</i> together and talk about it. (FT2)
	Thai	Firstly, I need students to learn science with happiness and joyfulness, so I try to help <i>students to be enthusiastic, exciting, and interested and like doing things through the hands-on experiment</i> . (TT2)
Content		
purpose of content knowledge	Fin	I think, some kinds of skills are used to learn to solve problem so that when have this <i>kind of problem in their everyday lives</i> , they will do the safe thing. (FT1)
	Thai	They should learn because <i>this lesson relates to their lives</i> . (TT2)
evaluation of student learning of conceptual knowledge	Fin	I give them <i>the test about</i> the last lesson, the concept, and also the things they have been doing for homework. Sometimes, I <i>check their homework</i> to see if they have the correct answer. Then, I assume that they have understood it. (FT3)
	Thai	If I would like them to have the right concept, I always let <i>them connect the circuit</i> by themselves and see it all together after that. They can see if it works or not and draw the diagram step by step. (TT3)
representation of concepts	Fin	I kind of make a conclusion about what they have been doing, and then, after that, we might look <i>at the textbook and give names to the concepts</i> . (FT3)
	Thai	They have to think together in a group about how to <i>draw the open circuit diagram</i> . After that, they have to draw it on the blackboard. When, we <i>check</i> any point that is missing or incorrect about the concept together. (TT1)

Appendix H

Examples of the original expressions and bold texts showing the deductive analysis units based on the GPK categories and sub-categories

GPK category				Examples of original expressions
Main	Sub-categories			
1. Classroom management	1.1 Content management			
	- Curriculum	Fin		You have to... I think <i>it controls our job</i> that we have to use it. I don't know how, do you say... kind of, well... it's kind of law. It has a static nature, being kind of... it's really... you have to follow it. You can't skip it. (FT2)
		Thai		It is important. It's <i>kind of a framework or guideline for teaching in</i> terms of what content should be taught, how difficult or deep of content should be taught, and how to teach. (TT3)
	- Teaching preparation	Fin		I check the student book and the teacher materials. Usually, it has very good points... kind of, <i>how to teach and what the main concept of this lesson</i> is, so I rely very much on the teacher handbook. (TF2)
		Thai		<i>I study all contents</i> for the semester, including how to organize the lesson and learning materials, and then write the week's lesson plan and think about <i>how to teach and in what way</i> . (TT1)
	- Learning materials	Fin		All kinds of <i>computer materials</i> exists. If there is something that I want to use, but it is not there, then I will make it somehow, and then, of course, I have to check if the... <i>school...err... equipment</i> for

		<p>this particular...err...I have checked whether it's working and whether there are enough batteries, wires, and so on. (TF1)</p>
	Thai	<p>Touchable, experimental, and authentic things...I like to use <i>the authentic things</i> for students doing an experiment. (TT1)</p>
-Students arrangement	Fin	<p>I form students into <i>groups of around 3-4 people</i> in one group. The maximum is four.</p>
	Thai	<p>Students are <i>grouped about 5-6 people</i> to a group in the LAB. (TT2)</p>
<p>1.2Conduct management</p>		
-Resolve discipline problem	Fin	<p>No...no...actually, I have taught many classes during my eight years. <i>I have never met a class that had discipline problems after teaching them</i>, so I think it relates to the interaction...between teacher and students, and the students want to act so that they please the teacher as they like the teacher and they respect the teacher, and then, if there is some discipline problem, then they usually are in the class.... (TF1)</p>
	Thai	<p>I <i>set the rules</i> in the classroom and in the lab and define their responsibilities in terms of taking care and keeping things orderly in the lab. (TT1)</p>
<p>1.3Covenant management</p>		
-Interpersonal relationships among students	Fin	<p>Well, <i>I carefully think about who will work in pairs</i> and who will be in the same group so that they would...err...they would work at... they can, and also, sometimes, it's</p>

			better if there is someone who knows a bit more and someone who doesn't know the subject that well so that someone can or that one who doesn't know can learn from the others. (TF1)
		Thai	I think work in a group is important to support students' relationships. For example, an excellent student can transfer knowledge or experience to other students in a group by discussion and cooperation. (TT2)
	-Relationship between teacher and students	Fin	I aim to be among the students as much as I can. I aim to walk around, help them, and encourage them as I have to ask, and yes, I also teach, but my moments of direct teaching are quite short. Mainly, I see my role to be that I help them to study. I help them to set their own goals, and I help them to reach their own goals. (TF3)
		Thai	Actually, students do not dare to come and talk to me, but I try to use conversation, not beating . I sometimes express to students that I care about them and worry about them all the time. (TT3)
2. Instructional methods	The social family of models	Fin	I have 26 pupils, so mostly, I form them into groups of 3-4. I think 4 is quite the maximum. They all can do, they all can try, and everybody can say their opinions. When the groups have an experiment ...every time, the real material and working in a group are used. (TF3)
		Thai	I always use the lab to teach students when they have to do some experiments in a group. (TT1)

<p>The information processing family of models</p>	<p>Fin</p>	<p>Well...I like <i>all kinds of problem</i>. We have the problem. How would you solve it? How would you make that thing light up? For example, if we talk about the electricity or things like that...what would you need, how does it work, why does it work...and so on. <i>They should find out...</i> (TF1)</p>
	<p>Thai</p>	<p>First, I stimulate them to think: what happens? Why is it like this? What is the reason? Then, I let them try to <i>find out or inquire</i> by themselves. (TT2)</p>
<p>The personal family of models</p>	<p>Fin</p>	<p>I need some <i>open-mindedness</i> from them and some <i>kind of curiosity</i>. I need the pupils to have <i>ability to ask</i>. They ask questions if they wonder. If they ask hard question to me, then I think they are interested. (FT3)</p>
	<p>Thai</p>	<p>I think that qualification is quite important in terms of how to learn, <i>how to think</i>, and how to <i>use skills to solve problems</i> and make decisions in every step. (TT1)</p>
<p>The behavioural systems family of models</p>	<p>Fin</p>	<p>No, I'm the book person, you know, so <i>they are in their own places</i> mostly, or we will go to the museum...the museum of the technology. Then, they are in small groups. (TF2)</p>
	<p>Thai</p>	<p>I have two rules in the classroom: the <i>teacher's rule</i> is about the agreement regarding time for teaching, experimenting, working in a group, and discussing; the <i>students' rule is about the positive and negative reinforcements</i>, such as group score, rewards, and giving stars. (TT2)</p>

3. Classroom communication	Teacher-student	Fin	I <i>ask them</i> about the prior knowledge regarding the lesson via questions in order to know their background. Then, we <i>discuss</i> on the topic of lesson together, such as electrical phenomena. I let them to work in groups, and I walk around to help them or <i>ask them about the experiment</i> . Lastly, we <i>discuss the results</i> and draw conclusions about the lesson concepts. (TF3)
	Student-student	Thai	Firstly, I try to make them think about what is happening, ask them questions, and let them have a <i>discussion in groups</i> . After that, they will perform the experiment in <i>groups with their friends</i> . They have to present the results of the experiment group by group. (TT3)
	No interaction	Fin	You know, after the experiment, we might look at the textbook and give them the concepts. Then, <i>they might do some exercises from the book</i> . (FT3)
		Thai	Students will have <i>their own lab book</i> . (TT3)