Examining Technological Knowledge and Reasoning in Icelandic and Finnish Comprehensive Schools

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Abstract

This research was undertaken in Finnish and Icelandic schools during the years 2013-14, in order to explore students' technological knowledge and reasoning at the ages of eleven and thirteen. The research considered the congruence between students' undertakings within Craft and Design education in the national curriculum and their ability to understand technological concepts. Data was collected using a questionnaire distributed to seven elementary schools and is highlighted with the researchers' reviews of the national curricula. The Icelandic part of the research was undertaken with 277 students and Finnish sample consisted from 317 participants. Technological knowledge and reasoning was measured with a questionnaire regarding mechanical systems connected with simple physical phenomena. The results highlighted that students should have been more familiar with the content of the survey as a result of their Design and Craft studies and the use of textbooks in other subjects, such as physics. We expected that there is more transfer effect between the content of curriculum and the results in technological knowledge and reasoning. In addition, some differences between boys and girls were found. This is explained by boys and girls different interests and obviously this has an impact on girls' motivation for learning about technology.

Key words

craft and design education, technological reasoning, technical literacy

Introduction

Basically, the goals of the Finnish and Icelandic national curriculums for Craft and Design are similar and aim to help students with the knowledge, skills and attitudes required to develop technological reasoning and increase their ability to solve problems (Framework Curriculum Guidelines, 2004; Autio & Hansen, 2002; Menntamálaráðuneytið, 2013). Both curriculums are based on models for learning that include technological knowledge based on handicraft skills and design principles within a problem-solving context. Teaching aims to empower students to manage their daily lives and successfully earn a living in society through innovative thinking and an entrepreneurial approach. The subjects also aim to develop students' understanding of how to assess, understand use and manage technology in a broad context, both at home and in the community. The goal is to enhance students' abilities to survive in their daily lives and to ensure personal growth in their personality.

Craft and Design lessons provide students with opportunities to learn about various technologies, by using hands-on activities and different design methods. Students realise their own designs through visible and usable projects. The knowledge and skills apply not only to the making of new artefacts, but also learning about technological reasoning and the maintenance of machines or handicraft tools. Learning practical skills can facilitate both technological knowledge and understanding through technological reasoning (Thorsteinsson, 2002).

Although, the goals in Icelandic and Finnish curriculum are quite similar, the main difference seems to be that Finnish Craft and Design education is nowadays officially named Handicraft and it is claimed that Technical craft and Textile craft should be compulsory for boys and girls in grades 3 – 9. However, in many schools Handicraft is in practice still divided into Technical Craft and Textile Craft in grades 5 - 9. Students' have to select just one of the craft subjects for several practical reasons like timetabling and the number of teachers employed. Because of this, boys will have more experience in the field of science and technology and therefore we can expect that they have better opportunities to improve their technological understanding and reasoning. In Iceland, Textile Craft is included in Home Economics while technological contents are taught in Craft and Design education for both boys and girls.
The article concentrates on the literature concerning the teaching of technological knowledge to young students. In addition, it defines related terms and subsequently explores several research projects. In order to evaluate students' technical understanding and reasoning in Iceland and Finland, a questionnaire was devised, concerning mechanical systems based on simple physical principles. A survey for students at the ages of eleven and thirteen was conducted in four Finnish and three Icelandic elementary schools. In practice, the researchers were interested in the present level of students' technological knowledge and the congruence between students' undertakings within Craft and Design education in the national curriculum. Although, it was not the authors' main intention to compare students

and two countries, a numerical analysis was carried out and some interesting differences were found between countries and gender to analyse further in discussion. The research questions were:

1. What is students´ present level of technological understanding and reasoning in Finnish and Icelandic elementary schools?
2. What is the relationship between students' Craft and Design education and their technological knowledge and reasoning?
3. Are there differences between students' technological understanding and reasoning in the two countries?

Technological literacy and technological reasoning

Reasoning is defined as *an action of thinking about something in a logical way, in order to form a conclusion or judgement* (The Merriam-Webster Online Dictionary, 2014). The ability of technological reasoning is important in the development of technological and scientific explanation and in students' ability to understand technological phenomena (Sutopo & Waldrip, 2013). In technology education, reasoning is essential in identifying and in establishing an explanation for a natural phenomenon (National Research Council, 2012). In addition, technological reasoning has been examined within the context of science and technology education and some scholars claim that, if students are to successfully learn about technology and science, they must be aware of the different concepts and processes and the relationships between them, in order to understand these within the context of technological knowledge (Hubber, Tytler & Haslam, 2010; Prain, Tytler & Peterson, 2009).

Technological literacy (TL) is the basis of technological understanding and reasoning (ITEA, 2007) and has been defined as *the ability to use, manage, assess and understand technology*. This encompasses three interdependent dimensions: (1) knowledge, (2) ways of thinking and acting, and (3) capabilities (Technically Speaking, 2006). The International Technology Education Association (ITEA) Standards defines a technologically literate person, in relation to working life, as '*understanding the significance of technology in everyday life and the way in which it shapes the world*' (ITEA, 2007). This definition places TL within the context of lifelong learning, in which every day learning within the workplace plays a central role. Accordingly, this places a focus upon the interrelations between human beings and machines (Suchmann, 2007), between technologies (Wallace, 2010), between technological artefacts and working culture (Hasse 2011) and between sensing and technology (Søndergaard, 2009). Thus, the philosophy of TL and technology is able to take into account the relationship between human beings and technologies (Dakers, 2005; 2006; Ihde, 2010; Ingerman & Collier-Reed, 2011).

Technological competence and understanding is important for students, in understanding the changes in the world of today. Furthermore, it enables citizens to play a part in the process of changing their surroundings. Technology can be described by means of how humans change the world around them in order to meet their needs and solve practical problems (Maryland Technology Literacy Consortium, 2014).

Craft and Design education and technological reasoning

As already explained earlier in this article, Finnish craft and design education is, at present, named *handicraft* and is divided in two different subject areas: Technical Craft and Textile Craft. However, there are common aims for both areas. The general aim of Finnish Craft and Technology education as defined in the Framework Curriculum Guidelines (2004) is to develop students' craft skills and support their self-esteem through enjoyable craft activities; it also aims to increase students' understanding of the various manufacturing processes and the use of different materials in craft.

Furthermore, the subject aims to encourage students to make their own decisions in designing, allowing them to assess their ideas and products. Students' practical work is product orientated and based on experimentation, in accordance with the development of their personality. The role of the teacher is to encourage pupils' independence, the growth of their creative skills through problem-based learning, the development of technical literacy and guide students'. In addition, gender issues are important throughout the whole curriculum (Framework Curriculum Guidelines, 2004).

In grades 1 – 6, technological themes are also taught as part of Environmental and Natural Studies. This forms an entity containing aims and content from science and technology, environmental studies and civics. The different areas of Environmental and Natural Studies are: matter and energy; organisms and their environments; the globe and its areas; man and the environment. In grades 5 – 9, there are two Science subjects Physics and Chemistry, as well as Biology and Geography they contain technology education mainly from theoretical perspective. The common aims of these subjects are to give a picture of man's living environment, and the interaction between man and the environment. Moreover, they help to realise the significance of individual and collective responsibility based on knowledge of the natural sciences and technology. One central purpose of the instruction is to help students understand the significance of the natural sciences and technology as part of human culture. The instruction should develop the knowledge and skills needed when students formulate their position regarding the values and questions related to life and the surrounding world. From the point of view of technology education, Physics and Chemistry teaching in grades 5 – 9 gives the student the necessary material to form a picture of the world, and it helps them to understand the purpose of natural sciences and technology as part of the culture. In addition to the traditional areas of Physics and Chemistry, the curriculum in grades 7 – 9 underlines the role of environmental education, entrepreneurship education, interaction of science technology and society and the utilisation of ICT.

Design and Craft in Iceland focuses on three main areas: handicraft, technological understanding and environment. Handicraft aims to increase students' knowledge of craft, materials and the use of tools, while technological understanding allows students to gain technological skill and reasoning. Study of the environment increases students' understanding of how their environment is affected by human vocational activities and of health and safety within the workplace (Menntamálaráðuneytið, 2013).

Within the Finnish and Icelandic curriculums, the aim of Craft and Design is to facilitate students' technological reasoning, in order to prepare them for participation in modern society and working life. Students learn practical skills via the development and creation of prototypes and systems and learn about technology as a field of human activity, using various tools from different design contexts associated with the transformation of energy, information and materials (Framework Curriculum Guidelines, 2004; Menntamálaráðuneytið, 2013). However, in Finnish Textile Craft there is more emphasis on art and design instead of technological contents.

The development of students' practical handicraft skills provides new opportunities to learn and utilise various technologies in their designs. Students put ideas into practice through practical projects and the knowledge and skills gained are applied not only to the creation of new products, but to the adaptation and maintenance of existing products, machines and other items.

Within the context of Craft and Design education, the link between activities and technological reasoning is important and provides students with opportunities to understand technological principles through their own experience. Waldrip, Prain and Carolan (2010) ascertained that when students learn to implement materials and tools, using both new and old technologies, they increase their understanding (Cox, 1999; diSessa, 2004; Greeno & Hall, 1997; Waldrip & Prain, 2006). In addition, Kohl, Rosengrant and Finkelstein (2007) asserted that an ability to demonstrate is a key in studying physical science and students with a higher ability to demonstrate principles are better at solving problems (Malone, 2008). Ainsworth (2008) claimed that multiple illustrations play a significant role in learning and constructing a deeper understanding in students, as they can integrate information from more than one source. Moreover, Rosengrant, Heuvelen and Etkina (2009) informed that students who frequently used representations were successful in mechanics tests.

Methods

The research was undertaken during years 2013-2014 and the participants were 11- and 13-year-old students from three schools in Iceland and four schools in Finland. The students were provided with a timeframe in which they needed to complete the questionnaire and the majority managed to complete it within thirty minutes. The Icelandic research was undertaken by 277 students and in Finland there were 317participants.

In Iceland participating schools were selected through convenience sampling. Convenience sampling is a method of sampling where the subjects are selected because they are easy to access. In addition, the selection is not supposed to be representative of the entire population (Coopers & Schindler, 2006; Cohen, Manion & Morrison, 2007). In the Finnish sample the schools were the same as in an earlier research project during years 1993-1996 (Autio, 1997). The schools were selected in order to ensure that schools with different curriculums as well as rural and city schools were represented.

In order to evaluate students' technical understanding and reasoning, a questionnaire was devised, concerning mechanical systems based on simple physical phenomena. Mechanical systems are systems commonly built for a single purpose and usually comprise of a few parts or subsystems. Simple mechanical systems are prevalent in our daily lives and are built in such a way that their parts are in synchronisation with each other, working towards a shared goal. A mechanical system consists of (1) a power source and actuators that generate forces and movement, (2) a system of mechanisms that shape the actuator input to achieve a specific application of output forces and movement and (3) a controller with sensors that compares the output to a performance goal and then

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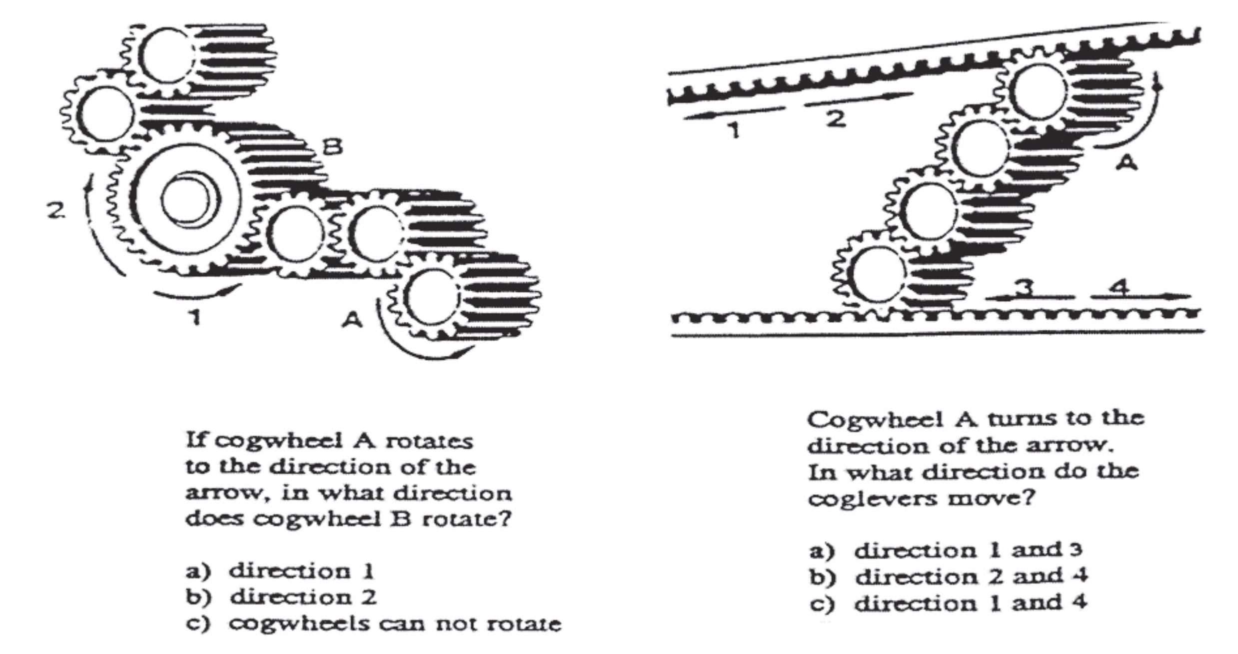

Figure 1. Examples from the questions in the questionnaire.

directs the actuator input. Power that flows through a mechanical system provides a way to understand the performance of devices ranging from levers and gear trains to automobiles and robotic systems (Merriam-Webster Dictionary, 2014).

The Oxford Online Dictionary (2014) defines the adjective 'mechanical' as s*killed in the practical application of an art or science, of the nature of a machine or machines, and relating to or caused by movement, physical forces, properties or agents such as is dealt with by mechanics*. Moreover, the concept can be defined relating to machinery or tools. A mechanical system is assembled from components called machine elements: these elements provide structure for the system and control its movement (Uicker, Pennock & Shigley, 2003). Example questions from mechanical contexts used in a similar questionnaire are presented in Figure 1.

The questionnaire originated in Finland by the ministry of labour and has been widely used as a test for students to see if they are suited to a career in mechanics. In an earlier research project (Autio, 1997) it was used as a part of a larger research instrument examining students' technical abilities. The questionnaire was based on 28 questions, with related figures. Each question included three possibilities, one of which was the correct answer. Structured and closed questions generate frequencies of response, making statistical treatment and analysis easy and enabling comparison across groups (Oppenheim, 1992). A questionnaire should be attractive and encouraging to respondents (Cohen, Manion & Morrison, 2007). Unfortunately, our questionnaire was from years 1993-1996 and some pictures may have looked old fashioned, but the layout and general impression of the questionnaire was sufficient to enable accurate answers from the participants. The questions referred to students' technological knowledge and reasoning supported by their education and life experiences.

It must be taken into account that the questionnaire was not originally designed to evaluate the curriculum of technology education. Some of the questions were quite difficult especially for the younger students, but this was necessary to ensure sufficient statistical dispersion for both 11 and 13 year-old students.

A numerical analysis was performed using the Statistical Package for Social Sciences software (SPSS), which provided total averages, the median, standard deviation and averages for different classes of questions. The relationship between variables was examined using Kendall's Tau test. As expected from the earlier research both Finnish and Icelandic samples approximately followed a normal curve. Reliability was not a problem either. In earlier studies by the Finnish ministry of labour reliability was measured to be 0.85 and in a research of students' technical abilities (Autio, 1997) reliability was 0.88.

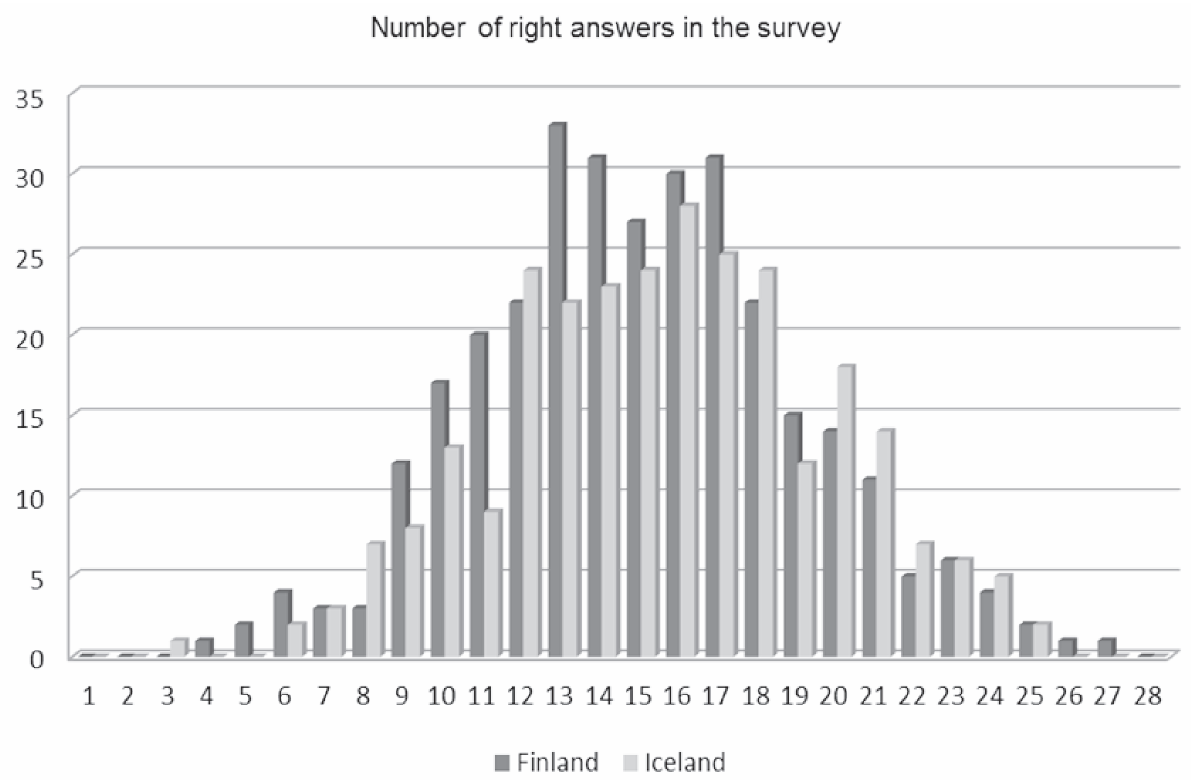

Figure 2. The number of Finnish and Icelandic students' correct answers in the survey.

Results

It was not the authors' main intention to generalise and compare the results between students and two countries as the main goal was to evaluate the present level of students' technological knowledge and reasoning. However, a numerical analysis was drawn and some interesting differences were found between countries and gender to analyse further in discussion. As expected the correct answers obey normal distribution. Figure 2 presents the number of Finnish and Icelandic students' correct answers in the survey.

The total average of correct answers to 28 questions was 15.5 (55.4 % of all questions) in Iceland and in 15.0 (53.5 %) Finland. The biggest category in Icelandic sample was 16 correct answers scored by 28 students. In the Finnish sample the biggest category was 13 right answers provided by 33 students. As expected, there were differences in the answers provided by the 11- and 13-year-old students. The average number of correct answers for 11-year-old students in the Icelandic sample was 14.7 (52.5 %) and in the Finnish sample 14.1 (50.4 %). In the group of 13-year-old students the small difference had almost disappeared as the average in Iceland was 15.8 (56.4 %) and in Finland 15.7 (56.1 %).

In addition, there were statistically significant differences between boys and girls in Iceland ($p=0.025$). In terms of the total answers provided by both sexes, the boys answered 16.0 (57.1 %) of the questions correctly, while the girls answered 14.9 (53.2 %) of the questions correctly. In Finland there were also statistically significant differences between boys and girls ($p<0.001$). Based on the total answers provided by both sexes, Finnish boys answered 15.7 (56.1 %) of the questions correctly, while the girls had 14.0 (50 %) correct answers. However, we must take into account that spatial skills and technological reasoning consistently improve with a simple training course and they are mostly due to previous experience in design-related courses such as technical drawing, as well as play with construction toys such as Legos (Sorby & Baartmans, 2000).

In Iceland, it was impossible to compare all the schools, as the numbers of students in different classes were dissimilar and the questionnaire was used just for 13-year-old students in one of the schools. In Finland, no statistical differences were found within the schools of similar curriculum of craft and technology education. Even in the University training school the results were the same as in rural areas, even though the school is usually ranked one

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	All students	11-year-old students	13-year-old students	Boys	Girls
Finnish students	15.0	14.1	15.7	15.7	14.0
Icelandic students	15.5	14.7	15.8	16.0	14.9

Table 3. The number of Finnish and Icelandic students' correct answers in the survey.

of the most successful in Finland. Thus, we can assume that the questionnaire measured technological reasoning, not just the context students learn in school.

Conclusions

The main goal of this study was to evaluate the present level of students' technological knowledge and reasoning. Furthermore, the study tried to find out if there was a relationship between students' Craft and Design education and their technological reasoning? It was not the authors' main intention to generalise and compare the results between students and two countries, although these results give interesting information for example in terms of gender issues. In light of the research results, the authors attempted to answer the research questions set out at the beginning of the study.

To answers the first research question: *What is the present level of students' technological understanding and reasoning in Finnish and Icelandic schools?* Our statistical analysis shows that the Icelandic students answered 15.5 of 28 questions (55.4 %) correctly. In Finland the amount of correct answers was 15.0 (53.5 %). The authors considered the outcome was fairly poor. The students' did not perform in the measurement of technical understanding and reasoning as well as expected. It would appear that there may be multiple reasons for this and thus the issue require further examination. However, in too many schools Craft and Design lessons are based on reproducing artefacts according to given models without any creativity. Students only occasionally plan and generate alternatives. Moreover, learning is too often focused on production skills with the aim of teaching students how to replicate demonstrated skill.

In Science education a common problem is that many teachers teach the typical presentation-recitation way, with students carrying out routine practical work or just solve simple textbook problems. These activities do not encourage students to construct scientific concepts or meanings; neither does it help them to see phenomena and objects in the environment (Arons, 1997).

The second research question was: *What is the relationship between students' Craft and Design education and their technological understanding and reasoning?* Bransford, Brown, and Cocking (2000) states that the ultimate goal of transfer is for students to generalize the knowledge they have learned in school to practical environments such as home, community, and workplace. Students should be able to apply their knowledge and skills inside and outside of the classroom, specifically to new cases. A large part of the Finnish and Icelandic national curriculum for Craft and Design is associated with technological knowledge, handicraft skills and design principles within a problem-solving context. Gaining practical skills can accommodate both technological knowledge and understanding through technological reasoning (Prain, Tytler & Peterson, 2009). Practising handicraft within Design and Craft provides students with the opportunities to learn about technology and to apply their skills in different settings.

However, the influence of the National Curriculum in Craft and Design cannot be seen directly from the results of this survey. Although there is evidence about the lack of transferring (Cree, & Macaulay, 2000; Pugh & Bergin, 2006); we expected that there is more transfer effect between the content of curriculum and the results in technological knowledge and reasoning. The students should have been more familiar with the content of the survey as a result of their Design and Craft studies and the use of textbooks in other subjects, such as physics (Menntamálaráðuneytið, 2013; Kohl, Rosengrant & Finkelstein, 2007). It seems that there is still much to do in practice, because learning in Craft and Design lessons is too often focused on production skills instead of technological reasoning.

In Finland Craft and design education is nowadays officially named Handicraft and it is claimed that Technical Craft and Textile Craft should be compulsory for boys and girls in grades 3–9. As a result of this, since 1996 boys have had much less technology education lessons than before. When comparing the results from an earlier research project (Autio, 1997) with our current study using the same research instrument, boys' technological knowledge and reasoning has diminished from 17.2 (61.4 %) to current 15.7 (56.1 %) correct answers in 28 questions. Especially, among 13-year-old boys the difference was statistically very significant (p=0.001) as the result has come down from 18.5 (66.1 %) to 16.5 (58.9 %) (Autio, 2013). In Iceland, Textile Craft is included in Home Economics while technological contents are taught in Craft and Design education for both boys and girls. We can assume that this is a relatively good setup for girls, which is supported by the result for Icelandic girls who scored 14.9 (53.2 %) right answers, which is much better than the 14.0 (50 %) scored by Finnish girls.

In answer to the third research question: *Are there differences between students'technological understanding and reasoning in Finland and Iceland?* Our empirical data from answers given in the questionnaire, indicated that there were some differences between the two countries. The total average of correct answers to 28 questions was in Iceland 15.5 (55.4 %) and in Finland 15.0 (53.5 %). The difference was clearly seen especially between Finnish and Icelandic girls (The average number of correct answers for girls in the Icelandic sample was 14.9 (53.2 %) and in Finnish sample 14.0 (50 %). Interestingly there was a difference between Finnish and Icelandic 11-year-olds as well, with the Icelandic figure of 14.7 (52.5 %) and 14.1 (50.4 %) in Finland. For 13-year-old students the difference was almost diminished, while the average in Iceland was 15.8 (56.4 %) and 15.7 (56.1 %) in Finland.

It is possible, that the difference between Finnish and Icelandic girls was due to different curriculums, while in Finland half of the Craft and Design lessons are reserved for Textile craft. In Iceland Textile education is part of the subject called Home Economics. The difference between Finnish and Icelandic 11-year-old students was interesting issue and it needs to be researched further, although at least part of the difference can be explained by different results from Finnish and Icelandic girls.

It was quite obvious that there were differences between 11-year-old students and 13-year-old students. In Iceland younger students scored 14.7 (52.5 %) and older 15.8 (56.4 %) correct answers whereas in Finland the results were 14.1 (50.4 %) for younger and 15.7 (56.1 %) for older students. Finnish results were consistent with earlier studies (Autio, 1997; Autio & Hansen, 2002; Autio, 2013), but relatively small difference between Icelandic younger and older students was difficult to explain. Icelandic curriculum gives common aims but leaves the teacher significant freedom in planning the content of lessons; for example, there may be a greater emphasis on handicraft and sustainable design than on technological studies. Hence, it was possible that there was a greater emphasis on technological studies for younger students and more traditional activities in handicrafts and sustainable studies for older students in Iceland.

Although, it was not the main goal of this research, we can't pass the differences between boys and girls. This issue is usually emotionally charged, although the difference in technological knowledge, especially in spatial reasoning corroborates with some other researches (Autio, 2013; Linn & Petersen, 1985; Voyer, Voyer & Bryden, 1995). Furhermore, it is not a surprise that boys and girls differ in their interests, which is consistent with several other researches (Autio, 1997; Autio, 2013; Johnsson & Murphy, 1986; Streumer, 1988). In addition, a review of research on motivation and transfer, Pugh and Bergin (2006) concluded that motivational factors can influence transfer. Although the research is limited and not wholly consistent, they also found that interest was related to transfer success when this interest was associated with the learning content.

Discussion

The aim of the research was to evaluate the present level of students' technological knowledge. In addition, the study tried to find out a relationship between students' Craft and Design education and their technological knowledge and reasoning. Instead, it was not the main intention to generalise and compare the results between students and two countries. However, these results give interesting information for example in terms of gender issues.

Every research has obvious limitations. In this case, we can assume that some of the questions were too difficult for especially younger students. This may have had some effect on the reliability and validity. Although to ensure reasonable standard deviation and normal distribution for both younger and older students; there should be both difficult and easier questions in the questionnaire. In addition, as seen in Figure 2 the correct answers obey normal distribution and the reliability measured in earlier studies was sufficient. In order to answer all research question fully, research incorporating a larger sample is required. In addition, the questionnaire needs to be improved and some questions needs to be updated with modern content.

Learning about technology is becoming an important aspect of modern education, as a result of the prevalence of technology within modern society. The elementary school subject Craft and Design aims to support students' technological knowledge and skills, with an emphasis on practical handicraft and innovative thinking using technological solutions. Developing students' practical handicraft skills provides them with opportunities to learn about and utilise various technologies in their design work, which results in a deeper understanding of technology and modern society. It also helps students to use technology in their creations via experiments that increase their ability to use such technology within society. In terms of technological literacy, students are required to demonstrate new skills and knowledge. Thus, within the Finnish and Icelandic curriculum, the subject of Craft and Design aims to develop advanced technological literacy and competence in students. The purpose is to prepare them for participation in modern society and working life.

A large part of the Finnish and Icelandic national curricula for Design and Craft is associated with technological knowledge, handicraft skills and design principles within a problem-solving context. Gaining practical skills can accommodate both technological knowledge and understanding through technological reasoning (Prain, Tytler & Peterson, 2009). Practising handicraft within Design and Craft provides students with the opportunities to learn about technology and to apply their skills in different settings. Malone (2008) stated that students with a higher ability to demonstrate principles are better at solving difficult problems. The subject of Design and Craft supports technical literacy and technical skills within a workshop environment and thus should provide students with practical experience. Students' earlier experiences should also have enabled them to answer the questions.

The influence of students' lessons in Design and Craft on the research outcome was not readily apparent from the results. It is possible that the students were unable to transfer the knowledge gained from their lessons at school to new circumstances. Nevertheless, the authors consider that although the transferring was not directly seen in the results, all technological knowledge and experiences the students gained through their education were beneficial for their future. It would have been interesting to compare grades from individual subjects (such as Design and Craft and Physics) with the outcome of the survey. It might also have been possible to formulate a new questionnaire based on students' technological studies in Craft and Design education.

Regarding the answers provided in the questionnaire, there were differences between the sexes. Kiefer and Sekaquaptewa (2007), Byrne (1987) and Halperin (1992) suggested that boys and girls differ in their interests and that this has an impact on girls' motivation for learning about technology. Another possible reason for this might be the different social expectations for boys and girls. The 1998 Ofsted report, entitled 'Recent Research on Gender and Education Performance', stated that technology is rated as masculine by pupils and is thus preferred by boys (Arnot, Gray, James, Rudduck & Duveen, 1998). The media frequently depicts men as experts in technology, while the structure of learning tasks for boys and girls is sometimes different, as is the nature of feedback in classroom situations and the organisation of classroom seating (Carter, 2011). However, because these factors are often subtle, they go unnoticed.

Due to several reasons we cannot fully generalise the results. Later on, the authors want to develop the questionnaire and reinforce a new research design, using a larger sample in order to ensure validity and reliability. However, the study did provide the authors new ideas to develop students' technological knowledge and reasoning and will be the basis for a future research using a reconstructed survey.

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