Design and Technology Education: An International Journal

24.3

Examining Estonian Schoolteachers' Attitudes Towards the Use of Applied Science Knowledge Within Craft Education

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Abstract

This article examines the possibility of supporting craft education by incorporating knowledge students have gained via science lessons: such knowledge largely refers to the mathematics and physics taught in Estonian comprehensive schools. Results were gleaned from interviews with craft teachers in Estonia, in order to establish their attitudes to the idea of integrating science with craft. Their ideas are presented here, along with a comparison of their understanding of the pedagogy. The results of the study address the following research questions:

1. *Do teachers consider the National Curricula supportive, in terms of integrating science knowledge in order to support craft education?*
2. *How do teachers recognise knowledge of science during craft processes?*
3. *Are teachers aware when science is integrated into their teaching?*
4. *What do teachers consider the benefits of such integration?*

The research demonstrated the pedagogy of integrating knowledge of science with craft as a novel idea, based on a process of merging the two knowledge models. The result of this process is a development of a new area of knowledge that can both enable students' understanding and their design and fashioning processes. Moreover, it relates to real-world phenomena and thus helps students with their ideation. Such new knowledge is achievable when knowledge from one of the fields is used in the other field, whether science or craft. The integration of science with general craft education is dependent upon both the National Curricula and a teacher's method of teaching.

Keywords

integration, science knowledge, craft education, pedagogy, Estonia

Introduction

The ability to transfer knowledge and skills gained in one subject to lessons of another subject or to real-life situations is an important ability within modern society. The term *transferring knowledge* basically means to learn something in one context and apply it in another (Fogarty, 1991). Thus, the skill of knowledge transfer is the foundation of knowledge integration. Due to a lack of integration of theoretical knowledge with practical life skills, the Estonian government has set out a new national curriculum for general education (Government of the Republic, 2014), with an emphasis on integration.

Today, the Estonian craft subjects have a technological focus, with the aim being to enable students to acquire the mentality, ideals and values inherent in modern society. They learn to understand options in problem-solving when creating new products and locating and utilising sustainable manufacturing processes. Students are taught to refer to various sources of information in their studies and analyse phenomena and situations. There is a focus on creative thinking and hands-on activities. Students are trained in the process of ideation and are taught to plan and prepare objects or products, in addition to presenting them (Ainevaldkond Tehnoloogia, 2011).

We can perhaps say that science is an element in craft. Science explains how technology works and technology is utilised in craft. Undertaking handicraft therefore provides students with opportunities to learn about and utilise various technologies, via hands-on. Part of the knowledge gained from practicing or learning craft can be called applied science (Thorsteinsson, 2002).

Applied sciences, according to Collins online dictionary (2019) is science that is put to practical use. It is the application of existing scientific knowledge to practical applications, like technology or inventions. Within natural science, disciplines that are basic science, also called pure science, develop basic information to predict and perhaps explain and understand phenomena in the natural world.

Various subjects, such as mathematics, chemistry, physics and history, are naturally linked with craft or are adopted within craft education. Although there has been lots of discussion about integrating the sciences within different subject areas in comprehensive school education, science as a subject has remained rather isolated and has not changed over the years. This may be the reason why many students are unable to understand the world around them via knowledge of science they have gained via general education, which in turn might de-motivate students in learning scientific knowledge.

If knowledge of science is not applied in craft lessons, this negatively affects students' attitudes towards solving various problems within craft education: building upon scientific knowledge aids the development of problem-solving skills. In terms of craft education, this concerns knowledge of various materials and the use of technology in making solutions. The best way to understand different technological processes and become aware of their validity within the world is to utilise them during applied craft work.

The article firstly introduces the historical background of Scandinavian craft education and the initiators' interest in *science,* and then the authors examine literature pertaining to Estonian craft education at the present time. The authors discuss the Estonian national curricula, outline the aims of The Ministry of Education in terms of cross-curricular school activities and present the results of their survey, in examining the status of students. Finally, they explain the research methodology, discuss the results and draw their conclusions.

Craft Education within Scandinavian Schools

Pedagogically-based craft education, according to Olafsson and Thorsteinsson (2009), was established in Scandinavia in the 18th century and was a school-based system of formative education, using the term *Sloyd*. *Sloyd* originally meant 'handy or skilful' and refers to the making of crafts (Chessin, 2007). However, the definition of Sloyd in relation to education refers to the discussion amongst philosophers of those times regarding the value of craft within general education (Borg, 2008). The purpose of Sloyd was to use craft as an instrument within public education with which to build the character of children, encouraging moral behaviour, greater intelligence and industriousness (Thorarinsson, 1891).

Sloyd was initially considered a school activity based on craft and was intended for personal development. The aims were pedagogical, rather than teaching students to make objects for their daily lives (Thorarinsson, 1891, p.7). Philosophers such as Comenius, Locke, Rousseau, Franke, Pestalozzi and Fröbel all underlined the significance of physical training and craft within general education. They influenced those educators who established the Sloyd movement in Scandinavia (Olafsson & Thorsteinsson, 2009).

The Finnish scholar Dr Cygnaeus (1810-1888) founded public schools in Finland in 1866 (Kananoja, 1989). He developed Pestalozzi's and Fröbel's ideas further and established craft as an obligatory subject which aimed to improve public education in Finland (Thorarinsson, 1891; Thorbjornsson, 2006). Handicraft training became a significant aspect of the upbringing of all children via general education. It supported an understanding between classes in society and included physical exercise (Bennett, 1937). Finland's Uno Cygnaeus and Sweden's Otto Salomon were major leaders in the development of a systematic Sloyd model for school education and they emphasised the usefulness of constructing objects through formal educational methodology (Kantola, Nikkanen, Kari & Kananoja, 1999). Sloyd had a notable impact on the early development of manual training, manual arts, industrial education and technical education in many countries (Bennet, 1926).

Science-Sloyd

Many of the initiators of pedagogical craft had an interest in science and gave their students tasks involving the fashioning of physical devices. The nobleman Locke (1632-1704) was interested in polishing lenses, while Francke (1663-1727) asked his students to make optical equipment and taught them how to use a lathe to polish glass they used in binoculars, for enlarging glass, microscopes and to examine perspective. Rousseau (1712-1778) wrote in his book of Emil: '*We should make physical equipment ourselves*' (Dansk Slöjdlærerforening, 1938: p.38).

In his book *About Goals and Resources for the Higher School Education*, Professor Kromann (1886) underlined the pedagogical value of students utilising physics in order to gain true scientific experience via craft. Kromann wrote: '*Instead of seeing the school's collection of physical devices at a distance without daring to investigate them, the student himself should make the most important equipment and thereby make sure he has really understood the principles of physics* (Kromann, 1886, p.38).

In 1888, a college teacher, Deputy Julius Petersen of Herlufsholm in Denmark, was involved in the assignment of connecting craft education with natural science, saying: '*Can you raise student's interest in the disciples of science - and it is not difficult - then it will be easy to give them the pleasure of making some devices by themselves, and, conversely, the one who works handy with physical equipment will not only become familiar with the principles, but, in reality, also acquire better insight into the effects of natural forces'* (Dansk Slöjdlærerforening, 1938: p.41).

In 1889, the Danish Association of Craft Teachers gave away eight physical models in a craft competition, suitable for use in Latin and public schools. In this collection was a torsional modulus of elasticity, a pendulum rack and equipment for thermal conductivity and freezing. The assessment committee, consisting of Mikkelsen (1849-1929), Slomann and Trier, stated: '*This path creates a connection between craft education and physics, which will be of great practical importance in both subjects; it is a good attempt to draw an unprecedented ideal as part of Danish craft education'*. (Dansk Slöjdlærerforening, 1938). Mikkelsen, the originator of Sloyd within Danish schools, taught science-craft to his teacher colleagues via in-service teacher courses, in order to prepare them in becoming craft teachers (Dansk Slöjdlærerforening, 1938: p.38).

The Estonian National Curricula 2011

School attendance is obligatory in Estonia for all students aged 7-17, meaning that they spend a total of nine years in public education. There are three stages to public education: grades 1-3 and grades 4-6 (primary education) and grades 7-9 (lower secondary education).

Attendance at school is obligatory until the accomplishment of basic education or until the student is 17 years old. Study in basic school consists of the first stage of study (grades 1 to 3), the second stage of study (grades 4 to 6) and the third stage of study (grades 7 to 9). The usual length of time for upper secondary school is three years (Andersen, 2003; Pöhikooli-ja Gumnaasiumiseadus, 2010). After finishing basic school education, students can continue their studies in a vocational school and, upon obtaining secondary school education in a vocational school or in an upper secondary school, they can go on to higher education, via either an institution of professional higher education or a university (Eesti Vabariigi Haridusseadus, 1992).

Subjects taught within craft and technology in Estonia support students in gaining the mindset, ethics and values integral to contemporary society. They learn to identify the choices they have in solving tasks or fashioning goods in an environmentally friendly manner, through the use of sustainable procedures. During lessons, students learn and examine phenomena and circumstances, utilising various sources of information. They integrate creative thinking and physical activity. During their studies and making of products, students ideate, design, plan and model, fashioning objects/products and then learning how to present them. The teacher supports students' initiative, entrepreneurial spirit and creativity and teaches them to appreciate a healthy lifestyle and economy. Classrooms are seen as a positive environment where students' work and development are recognised. Through their studies, students develop their ability for working and collaborating and strengthen their critical thinking, including the capability to examine and assess (The Estonian Ministry of Education and Research, 2011b).

The subject field of Craft and Technology includes the following subjects: Handicraft, Technology Education and Handicraft and Home Economics. Handicraft is first taught in grades 1 to 3 for girls and boys together. After grade 3, students are divided into study groups based on their wishes and interests, selecting either Technology Education and Handicraft and Home Economics. This allows students to study in larger detail the subject that they are interested in. There is a compulsory exchange of the subjects each year. In addition, a project-based learning, supervised each year by both teachers, is conducted for about 25 % of the school hours. These projects are integrated with projects in other subjects or conducted between different classes as well as with schoolwide and longer-term events between schools (SFT, 2010; NC, 2010).

Craft and Technology, within the Estonian National curriculum, aims to facilitate students' technological reasoning, in order to get them ready to take part in the modern working life and society. Students gain handicraft skills via the development and making of prototypes and systems and learn about science and technology as a field of human activity, using various tools from different design contexts associated with information and materials and transformation of energy, (NC, 2010). The students' handicraft training increases their skills and an opportunity to utilise and learn about various technologies. Students put ideas in practice by making practical projects and the knowledge gained are applied. Students have to study and analyse phenomena and situations, using various sources of information.

Focus on Cross-Curricular Activities

Since the inception of Sloyd in Estonina, craft subjects have been developed in accordance with various social and educational needs; thus, the ideology and goals of craft education and general education are different. One of the focal points in modern education is inter-subject integration, in terms of its benefits in enabling individuals to understand and use modern technology and to play an active role in the evolution of a modern democratic society (Kuusk, 2010). The integration of subjects decreases the gap between them and overcomes their isolation. By combining the knowledge and skills attained from different subjects, students may improve their understanding of the everyday world outside school (Hitsa, 2019; Autio, Soobik, Thorsteinsson & Olafsson, 2015; Vars, 1991).

In 2010, the Parliament of the Republic of Estonia introduced a new law for comprehensive schools and high schools and a new rationale was subsequently presented within the new national curriculum. The aims of the new curriculum were to create systematic inter-relations between subjects in order to enrich students' learning experiences. Furthermore, there was a focus on developing students' general competences and avoidance of overloading them. In view of the cross-curricular aims, curriculum development must contribute to the fulfilment of the general educational goal of increasing students' skills, in terms of utilising knowledge of natural sciences in various areas and increasing their interest in technology and technological studies (Haridus- ja teadusministeerium, 2011a).

The Estonian National Curricula focuses on increasing students' general competence in technology and this is achieved by giving students cross-curricular learning tasks based on identifying and analysing certain technology in order to be able to create knowledge and use this to solve problems. This is further described in section 1.5.1 of the National Curricula, which states: '*focusing on technology inside craft education relies on knowledge acquired in other subjects, offering opportunities to achieve, through applied activities, an understanding that all knowledge is connected and applicable to everyday situations. Abstract analysis is supplemented with possibilities of seeing, touching and testing, which lead to a visible result. Subject projects enable connections to be made between subject fields, within the subject field and with other subjects*' (The Estonian Ministry of Education and Research, 2011a, p. 327).

A Survey to Examine Students' Abilities in Utilising Knowledge of Other Subjects within Craft Education

At the end of the 19th century, the Estonian education system was already concerned about the chaotic presentation of study material, in which links between new and old material were missing (Lind, 2005). They were also concerned there were too few students graduating in subjects within the remit of science and technology.

One important indicator of students wanting to obtain a profession within the area of science and technology was viewed by educators as the awareness of comprehensive school graduates to utilise knowledge of applied sciences in solving work-related problems. To clarify this, a test was conducted in Estonia in the spring of 2005 (Kikkull, 2009), involving students in the final year in comprehensive school. The tasks measured students' abilities in utilising basic mathematics and physics to solve general technical problems. The participants were all boys and the test was conducted in both town and country schools. The research concluded that the students' skill in solving technical problems were generally poor.

The most difficult task the students faced could be solved by applying mathematics. They had to calculate how much paint was needed to cover a plywood surface according to its surface area and only 29% of students were able to answer the question. A particular difficulty they had was calculating the size of the surface area upon having identified the geometrical shape of the object. Tasks that required knowledge of physics, however, were managed much better (with a success rate of 74%) than those tasks that required knowledge of mathematics (success rate of 42%). The research concluded that physics-related tasks were closer to real-life technical situations than those tasks based on mathematics and thus were more appropriate for students. It also highlighted students' difficulties in solving tasks within craft using knowledge from different subject areas.

Methodology

The aim of the research study was to examine Estonian schoolteachers' attitudes to utilising knowledge of applied science in order to support craft education within Estonian comprehensive schools.

The objectives were to:

a. *Examine the role of teachers in this context*
b. *Identify any pedagogical issues relating to the use of science knowledge in support of craft education*
c. *Observe the learning process in action, in terms of scientific knowledge*
d. *Observe if any applied knowledge was in use during lessons*
e. *Observe if there was collaboration amongst teachers.*

The research questions were as follows:

1) *Do Estonian craft teachers follow the National Curricula, in terms of utilising science knowledge in support of craft education?*
2) *Are teachers aware of those times when science integration arises in their teaching?*
3) *What do teachers consider the benefits of such integration?*

The research was based on twenty semi-structured interviews with school teachers from various regions within Estonia, in order to establish their attitudes towards the integration of science with craft. Five of the teachers were with a master's degree. Having teachers with a wide range of roles and experiences helped to ensure quality, reliable data.

In semi-structured interviews, researchers normally use open-ended questions, which require descriptive answers (Smith, 1995). The aim of this is to gain respondents' points-of-view, rather than generalising about their behaviour and activities (Smith, 1995). Throughout interviews, the interviewer applies suitable probing techniques, which encourages participants to speak further (Cohen, Manion & Morrison, 2005). However, such probing has to be neutral so that it will not redirect interviewees to other subjects.

The researcher attempts to build a rapport with respondents, with the interview taking the format of a conversation (Smith, 1995; Willig, 2001). Questions are asked when the interviewer feels it is appropriate to ask them and these may be prepared questions or questions that arise in the researcher's mind during the interview. This sense of rapport implies ethical responsibilities and interviewers have to be sensitive, with regards to respondents' readiness to talk about prearranged topics. Semi-structured interviews are designed to create a detailed description of respondents' perceptions of a given matter (Cohen et al., 2005). In half open interviews the researcher has the responsibility of ensuring that the interview does not diverge from the research question (Cohen et al., 2005) and a carefully constructed schedule can help with this (Smith, 1995; Willig, 2001).

All interviews were based on a semi-structured interview schedule developed from the literature and the survey, as many questions were addressed by interviewees' personal stories. The software Transana 3.21 (Transana, 2018) was used to analyse the data arising from the interviews and open coding was used in data analysis, in accordance with grounded theory principles. In open coding, researchers form initial categories of information regarding the phenomena that was examined (Creswell, 1998). They approach the data with open minds, in order to generate as many ideas and issues as possible. Similar results are categorised into main categories and are drawn upon in discussions and conclusions (Emerson, 1995).

The data was processed as follows:

1. *Raw data was collected;*
2. *Data from each interview was then summarised: for example, the teacher interviews were first summarised separately and then placed together, in order to generate categories;*
3. *These categories were then interpreted. Patterns were identified and connections made creating a coherent narrative with quotes from the interviewees;*
4. *Conclusions drawn;*
5. *The process was repeated for all the interviews listed above;*

6. *Finally, the categories from all data sources were brought together under overall categories;*
7. *The categories were then used to triangulate the findings and were analysed in relation to each other and the literature and conclusions were drawn.*

Discussing the Results Arising from the Enquiry

In this section, main categories established during the enquiry are defined and the results outlined:

a. *Learning to Use Hand Tools and Machinery*
b. *Integration and the Craft Syllabus*
c. *Integration of Craft and Applied Sciences*
d. *Teacher Cooperation*
e. *The Effects of Integration*
f. *Realisation of Integration*

a. Learning to Use Hand Tools and Machinery

The research shows that the students, in general, learn to use hand tools before they learn to use machinery. They gain technological knowledge and skills via learning processes that are largely based on their own experiences. However, they sometimes use hand tools and machinery together, but this is dependent on the aims of a lesson. Also, if the teacher considers manual work too demanding, materials may be prepared using machinery before the utilisation of hand tools. As Kirkull (2009) stated, machine work is not a good method with which to teach handicraft. He further claimed that by undertaking work manually and then finishing it off using machinery, students can both gain knowledge of the use of machinery and the satisfaction and pride in handicrafts: gaining knowledge and a deep understanding and respect in the value of craftwork through the use of hand tools is an important aspect of craft. Some scholars argue that, if students are to effectively learn about the use of technology, such as machinery (Hubber, Tytler & Haslam, 2010), they must be conscious of concepts and processes and the associations between them in order to understand these within the context of technological and scientific knowledge (Prain, Tytler & Peterson, 2009).

Teachers were often excluding students from using machinery due to safety regulations. They also asked them to avoid becoming too dependent on the use of machinery in order to develop their handicraft skill (for example, when they queue to use a machine for a single minor cut). Due to this, the teacher has to establish a syllabus with rules that support the relationship between learning to use hand tools and machines, based on logic and scientific knowledge of machines and safety rules. Suchman (2007) considered that there is a focus on interrelations between human beings and machines inside the craft classroom (Wallace, 2010). Furthermore, he argued that there are interrelations between technological artefacts and working culture (Hasse, 2011) and between sensing and technology (Søndergaard, 2009). Thus, the philosophy of technology is able to take into account the connection between humans and technological knowledge (Dakers, 2005, 2006; Ihde, 2010; Ingerman and Collier-Reed, 2011).

Teachers feel that hand tools offer greater potential in explaining the various aspects of work processes. This may derive from the fact that, when working with hand tools, the student experiences the material with his other senses. Maintaining handicraft skills is also regarded as important because it improves students' sensory motor skills. According to Borg (2006), it is better to perform craft processes in order to understand them and to become familiar with them. Moreover, the improvement of practical handicraft skills equips students with the opportunity to learn about and utilise numerous technologies during their design-making (Kikull, 2009). Students put ideas into realisation through practical work and the skills and knowledge gained are not only practical in terms of creation of new products, but also in the understanding of existing products, machines and other objects (Thorsteinsson and Olafsson, 2016).

b. Integration and the Craft Syllabus

When teachers set up their school syllabus, they must follow the National Curricula and be critical, in terms of weighing up the any benefits for the subject of craft. In general, it is also wise to reflect upon and evaluate new ideas and approach them with an open mind. This can help a teacher to validate new ideas and thus ensure reliability and confidence in further actions (Tart, 2009). The present national curriculum is focused on integration and, generally, encourages teachers to approach craft working with general topics and, when building up general skills, integration is also handled in a cross-curricular way (Government of the Republic, 2014). However, some teachers simply understand this as an innovation in craft education (Kirkull, 2016).

Craft teachers write their own syllabus, but do not always follow the national curriculum. They generally adjust the syllabus in accordance with their prior knowledge, rather than placing new emphasis on the national curriculum. Though the syllabus did not lead them directly towards integration, participants in the research believed that craft involved inheriting knowledge from other subjects, particularly mathematics and physics, and that a good teacher might identify these connections and utilise them in the classroom. According to Syrjäläinen, (2003: 60) teachers build metacognitive supporting structures for the student when they finish different tasks, problems or learning objectives.

A syllabus may also guide teachers by emphasising the use of scientific knowledge in craft, but is a document that provides teachers with freedom and flexibility: it does not necessarily direct craft teachers to integrate their subject with applied science, but it does not forbid it. As expected, teachers are afraid to move towards science and consider that craft may become a supplementary subject under science. As Akgun, Isik, Tatar, Isleyen & Soylu. (2012) argued, although much has been said about the need for integration, subjects in basic schools have remained largely isolated.

Most Estonian craft teachers, according to Kirkkull (2012), base their teaching on reproduction of known artefacts. Therefore, students have difficulties to use theoretical knowledge they have learned to solve live situations because they have not used it to solve problems through practical work inside craft classes. Insufficient use of possibilities to integrate science knowledge with craft during lessons may be the main reason why students cannot use knowledge from science outside the school. Moreover, more time needs to be given for creativity and experimentation (Kikkull, 2012). That would offer students to implement knowledge from other subjects' areas to resolve tasks during lesson.

c. Integration of Craft and Applied Sciences

Teachers in the study believed knowledge of applied sciences, in terms of craft, to be both practical and beneficial. They also considered some elements of applied sciences or science as an integral part of craft, stating that applied sciences were always present, but that it is important to clarify their presence when working with students as they have difficulty in identifying this.

Science, technology and craft are connected. Science explains how technology works and the usefulness of scientific knowledge becomes very clear when technology is utilised in craft. Undertaking handicraft within Craft lessons provides students with opportunities to learn about and utilise various technologies, via hands-on. The knowledge and skills gained are applied not only to the making of new artefacts, but also to the adaptation of existing technology and the maintenance of machines or handicraft tools. Gaining practical skills can facilitate both scientific knowledge and understanding through technological reasoning and makes it easier for students, to solve world problems (Thorsteinsson & Olafsson, 2016; Malone, 2016). Ainsworth (2008) underlined that importance of being able to explain applied science in many ways and the importance of giving students information from many sources as it would deepen their understanding in science.

According to Perkins and Salomon (1992), the utilisation of knowledge of applied sciences in craft is vital, as it helps students to view the world around them holistically and from different angles. Students, however, usually consider subjects as detached and separate from each other, with no direct connections. Also, in such learning situations, the formation of students' comprehensive view of the world is not supported (Kikkull, 2016).

The teachers considered that sciences were very theoretical and far removed from any practical work and argued that teachers must learn the practical aspect of the subject, in order to be able to apply it in the classroom. They also asserted that the integration of applied sciences in craft class projects a rather dull and uncreative phenomenon. While a variety of integration approaches can be found in theory (Mustafa, 2011) and the Estonian

National Curriculum for Basic Schools (Government of the Republic, 2014) sets out the requirements for the realisation of integration, teachers lack the knowledge and experience of functional principles and the directive role of syllabi and textbooks have to be moderated (Kikkull, 2016). The research indicated that the integration of any subjects in schools was weak and that subjects were isolated, due to the structure of the national curriculum. The best integrationists were those teachers who taught two subjects; e.g., a craft teacher who also taught mathematics. Akgun et al. (2012) stated that, although much has been said about the need for integration, subjects in basic schools have remained mostly isolated for both Estonian as well as foreign studies (Akgun et al., 2012; Kikkull, 2009; Soylu & Isik, 2008) They demonstrated that students' subject knowledge remains significantly below if they don´t get an opportunity to utilise the subject knowledge of natural sciences in various areas.

Teacher participants in the research believed they were utilising applied science via the craft process, but that it was also both important and beneficial for students to understand it theoretically during classes in other subjects. The use of applied sciences enables students to better plan their work and the teachers also considered it important for students to gain intuitive information in order to enable their understanding of different principles via practical craft lessons. This ability to receive intuitive information has been referred to in various ways in the literature: The psychologist Tart (2009) called it *direct knowing* and it has also been described as ……*naked-awareness* (Targ, 2004). Many craft scholars and researchers describe having experienced information acquisition during their work (Larsson, 2001; Uusikylä, 2008).

The craft teachers who took part in the study were independent but knew little about how teachers can utilise applied sciences in craft. They understood the value of experiments within applied sciences, but were not ready to adopt this as part of their daily routine, with one stating: *Teacher do not interlink subjects; it is not common for them to see relations with other subjects in terms of making with your hands.* Perhaps the teachers just needed support to get started in this. Braunger and Hart-Landsberg (1994) noted that teachers implementing integrated education require help in overcome the inertness of acting alone. Other researchers have addressed support for interdisciplinary integration, such as Jacobs (1991) in his recommendations for the effective application of integration and Drake (1993) in his discussion of teachers' misconceptions about integration.

The teachers argued that teacher training was too subject-centred to prepare teachers for the integration of subjects and that, later, this would depend on their own initiative. Teachers should work together, given that the fundamental principles of craft and science are easily combinable. Younger teachers, open to new ideas and directions, would also be more likely to work with integration than teachers with longer work experience. While a variety of integration approaches can be found in theory (Mustafa, 2011) and the Estonian National Curriculum for Basic Schools (Government of the Republic, 2014) sets out the requirements for the realisation of integration, teachers lack knowledge and experience regarding functional principles and the directive role of syllabi and textbooks is moderate (Kikkull, 2016).

Participants in the study believed that applied sciences have a slightly higher hierarchical position than craft, but stated that people require such skills for solving real-life problems. However, they considered examples and demonstrations in applied science classes too subject-centred and not conducive to real life. According to Kikkull (2009, 2016), the learning process in basic schooling is characterised by conflict between the natural integration of craft and other subjects and the realisation of this. Such conflict affects students' ability to apply subject knowledge outside that specific subject; i.e., they lack the readiness to use acquired knowledge in solving real-life situations, particularly concepts and skills that they have not yet learned directly.

The teachers underlined the importance of teaching students everyday problem-solving through the application of theoretical knowledge, as this helps them to function in society. As one of the teachers said: *People do not just consider the theoretical aspect of processes, they simply undertake them. The student for example has to know how glue works in order to be able to glue wooden pieces properly together.* Regretfully, the teachers did not fully acknowledge this problem. According to Skolverket (2005), within the subject of craft, it can be clearly seen that students are in tune with practical problems, but that skills gained are rarely visible outside the classroom.

d. Teacher Cooperation

The teachers, most often, worked alone rather than together but communicated regularly during meetings. However, when schools were running interesting theme weeks or a single project, there was active teacher cooperation. Co-operation between craft and science teachers is not an everyday occurrence. Most cooperation was achieved with maths and physics teachers, the benefit of which is viewed by craft teachers as students' awareness of cross-subject relationships (Kirkull, 2016). Craft teachers are generally cooperative and open-minded and are ready to engage in various forms of cooperation with teachers of other subjects; however, they require the organisational support of their school in this (Kikkull, 2016).

Teachers felt their cooperation could be better, but considered it time-consuming as it required extensive planning. They also considered school subjects were competing for time. One teacher said: *Regretfully, at the moment, due to the number of classes and volumes of class curriculums, subjects are more competitive than cooperative.* An analysis of the study showed that Estonian teachers feel overloaded; they lack resources and subjects are separated within schools. Similar issues were also highlighted by Braunger and Hart-Landsberg (1994), who noted that teachers implementing integrated education required help to overcome the inertness of acting alone.

e. *The Effects of Integration*

All interviewees considered integration should be based on a single subject supported by using knowledge from other subject areas. They found craft in combination with applied science a good method of helping students to understand world phenomena. Understanding such phenomena and patterns via craft can help students to understand the world from a theoretical viewpoint; thus, craft ought to be utilised as a tool to understand applied sciences. According to Kikkull (2009; 2016), schools should integrate craft with other subject in natural manner via practical work as it would help students to better understand the world around them and to solve real-life situations.

The teachers argued that craft can make mathematics enjoyable for students, rather than it being a difficult and abstract subject. They stated craft was rated of high value amongst students and that this may also increase their interest in applied sciences. It was believed that students' interest in studying technical subjects is dependent on how the teacher stimulates interest in students. A teacher can be a guide, but general craft studies do not prepare students for any specific profession. It is important to meet students' interest, but difficult to meet every students' needs. Both Estonian and foreign studies (Akgun et al., 2012; Kikkull, 2009; Soylu & Isik, 2008) have shown that students' subject knowledge remains significantly below the level required to solve domestic and technical problems.

f. *Realisation of Integration*

During craft classes, teachers integrate applied sciences without acknowledging it themselves, through demonstrating, testing, experimenting and explaining applied phenomena noted throughout the work process. Problem-based teaching and process-thinking is often used, which in turn encourages students to define and solve problems (Kikkull, 2012). There is an attempt to find suitable tools, materials and processes in order to solve problems, followed by experimentation and analysis of the outcome. Subject integration seldom takes place, in terms of cooperation between two teachers on the basis of an optional subject. Current perspectives on knowledge, according to Petrina (2007), questioned the view that knowledge is information, or a collected database that can be used when the circumstance arises. He further argued that knowledge is passive in the process of craft and technology and that it is utilised when required.

The aim of craft education is not to demonstrate the phenomena of physics, but to deal with problems within craft. Students, normally, focus on making objects rather than studying applied science. Teachers believe students have difficulties in understanding abstract concepts and find it hard to establish whether information originated from one specific subject. The key to this is for students to solve problems on the basis of what they already know. Borg (2006) argued that, in order to understand the processes relating to craft in the environment around us, it is best to perform the processes ourselves and thus be convinced of their validity. Knowledge, according to Petrina (2007), generates action and, of course, action or experience generates knowledge. Knowledge is both the process and product of innovative act.

The teacher plays a vital role in this situation. He can guide students through the working process; they make them achieve quality work, even if they do not understand the process very well. It is thus better to give students support in understanding new knowledge during their work. He has to give them flexibility so that they can make their own decisions and finally understand problems through experience. However, the risk with this teaching method is that a student may not gain enough knowledge of materials and tools and thus improve his craft skills. Therefore, the best teaching method would be both to guide and support in order to ensure students fully understand concepts: this also occurs through students' reflections and communication. The connection between a teacher and a student, moreover, consists of multiple interconnected perceptions that arise from their interactions (Pianta, Hamre & Stuhlman., 2003).

Conclusion

The research focused on integration of craft education and applied sciences in Estonian comprehensive schools. The data indicates that, applied sciences within the comprehensive school remain isolated within their subject fields; thus, students are unable to apply any acquired knowledge outside of the school environment and they lack the motivation to seek such knowledge. They also lack the mindset required to apply their knowledge of science in order to solve problems, both at school and in their daily lives (Kikkull, 2009).

A well-organised integration of craft and applied sciences in comprehensive schools would perhaps help to overcome the aforementioned situation. The integration method currently used in schools lacks efficient planning and should be visible in curricula guidance for teaching, schoolbooks and teaching materials. In-service course training for practising science teachers also lacks an introduction of applied teaching principles and algorithms in its didactics.

The authors of this research address the aforementioned problem and hope it will assist educators within the area of craft and science, in order to develop principles and measures for forming integrative knowledge in students. This could be the basis for:

- *Improving understanding of technical phenomena through an exploration of their scientific nature*
- *Applying knowledge of applied sciences in other subjects*
- *Motivating students' willingness to learn applied sciences*
- *Motivating students to undertake technical studies after compulsory education.*

Generally, Estonian craft teachers teach students handicraft and machine work via trying, testing and experiencing, rather than building upon technological knowledge. Thus, utilising knowledge of applied sciences may be beneficial for the learning process in craft. The need for knowledge is greatest during the work process: it is vital in students gaining a sense of both material used and work processes. As Borg (2006) asserted, in order to understand the processes that relate to craft in the environment around us, it is best to perform the processes ourselves and thus be convinced of their validity.

The craft syllabus offers little help for teachers, in terms of the integration of science. It falls to teachers to utilise knowledge of science in craft lessons and this is dependent upon their own awareness, initiative and values. There is no doubt about the necessity and usefulness of integration, but there are some conditions on its introduction:

- *It should be interesting and motivational;*
- *A craft class must maintain its subject focus and not become an ancillary subject;*
- *Integration must shape a consistent world-view, not simply a strict understanding of a single applied sciences subject;*
- *An attempt to organise teaching on a topical basis by teaching supra-subject topics of similar substance simultaneously in different classes;*
- *Integration should be based on problem solving and analysis of the work process.*

As subjects are isolated, due to the curriculum, an initial step towards integration could be to utilise the capabilities of those teachers who already teach two subjects. Teacher training in craft should also be based on integration.

Answering the research questions

The three research questions set in the beginning are answered in the sections below:
Question one: *Do Estonian craft teachers follow the National Curricula, in terms of utilising science knowledge in support of craft education?*

Answer: The teachers, in general, follow the National Curriculum but many of them do not follow it in terms of applied science. They rather write their syllabus in accordance with their prior knowledge and skills. Their teaching is based on reproduction of known artefacts instead of focusing on integration and applied science and students' have limited freedom to create their own designs. Many of the teachers, also, consider integration and use of applied science a useless innovation in Craft, particularly mathematics and physics. Teachers are afraid to move towards science and consider that craft may become a supplementary subject under science.

Question two: *Are teachers aware of those times when science integration arises in their teaching?*

Answer: The teachers, in commonly, considered a good teacher able to identify connections between craft and applied science and capable to utilise them with students inside the classroom without being supported by the National Curriculum.

Question three: *What do teachers consider the benefits of such integration?*

Answer: All of the interviewees considered craft in combination with applied science a good method of helping students to understand world phenomena. They, moreover, thought that understanding such phenomena and patterns via craft could help students to understand sciences, mathematic and the world around them. They, also, considered such understandings were required for solving real-life problems. The teachers argued that craft can make mathematics enjoyable for students and science more interesting, rather than considering it being difficult and abstract subjects. They also believed that students' might become interested in studying technical subjects.

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