



**KTH Education and Communication
in Engineering Science**

Bridging the boundaries between D&T education and working life

*A study of views on knowledge and skills in product
development*

HELENA ISAKSSON PERSSON

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Department of Learning
KTH School of Education and Communication in Engineering
Science
SE-100 44 Stockholm
Sweden

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Abstract

In Sweden upper secondary school education is organised in programmes. One of these programmes is the Technology programme that covers five orientations, one of which is *Design and Product Development*. This thesis is based on the idea that a clearer link between upper secondary school and the demands of professional life in the area of product development is beneficial to both students and industry.

Product development is performed in cross-functional teams where understanding of others' competences is important. It is therefore argued that, in order to enhance both teaching and learning, interdisciplinary considerations need to be explored. In this thesis, we turn to engineers and industrial designers. The aim of the present study is to get professional actors' views on knowledge and skills needed within the field of design and product development and to examine whether there are key areas that facilitate an interdisciplinary approach suitable to focus on for educational purpose. As artefacts play a central role in product development the informants' views on different products/artefacts are also examined. This reasoning results in an a two-part overall research question

(a) What thoughts do professional engineers and industrial designers express regarding necessary knowledge and skills, and (b) what relevance does this have for upper secondary school teaching of product development?

This overall research question is examined through two sub-studies, both performed at the same time, one conducted as a semi-structured interview and the other using the *repertory grid technique*. Twelve engineers and industrial designers are interviewed. The first study examines the informants' thoughts on knowledge and skills required in their work. The same informants' interpretations and valuations of artefacts are examined in the second sub-study.

In sub-study 1 two topics of significance to the informants are identified. These topics are: [1] *To act within the team* (Figure 4). The

ability to navigate and position oneself within a team is, according to the interviewees, a necessary skill in design and product development work. Its character can be described as including specific vocational knowledge and skills as well as issues of general and interdisciplinary nature as collaborating, compromising, communicating, and leadership. The second topic [2], *to CAD* (Figure 4) includes both skills with CAD software and the ability to understand relationships between a CAD model on screen and the final product.

The third topic [3] - *a valuation of artefacts* - is the outcome of sub-study 2 (Figure 4). This topic was found interesting and further analysed, resulting in the development of a comparison procedure. The result demonstrates how the interviewees interpret and discuss artefacts' functionality linked to cultural values.

These three topics are found to be relevant for technology education at upper secondary school level geared towards design and product development to explore. *To act within the team* can inspire the development of activities in which project and teamwork are in focus. The purpose of the CAD model in product development is to visualise a product that does not yet exist. *To CAD* highlights the complexity of this visualisation ability. In the educational context the students can train this ability by developing digital models into physical models or prototypes. *Valuations of artefacts*, the interviewees associate artefacts' functionality with certain characteristics. In education students should learn that we are not neutral in our relations to products and other artefacts. In conclusion, a need for teachers to discuss artefacts from different perspectives such as sustainability, usability, identity and so on is also pointed out.

Keywords: *Upper secondary school education, Design and product development, Technology programme, Repertory grid technique, Artefacts.*

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Helena Isaksson Persson, Stockholm 11 January 2015

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PART I

1 Introduction

In Sweden upper secondary school education is organised in programmes. One of these programmes is the Technology programme (further described below).

This thesis is based on an interest in developing education in one of the orientations in the Technology programme - the *Design and product development* orientation. The design of the study described below should be seen in the light of my previous experiences as a teacher at this orientation.

The starting point is the idea that a clearer (and closer) link between upper secondary school, design and product development education, and the demands of professional life as engineer and/or designer in the area of product development is beneficial to both students and industry. Discussing knowledge in education by examining knowledge outside that context may seem counterintuitive. However, as emphasised in the curriculum (Skolverket, 2013b), throughout our lives, we need knowledge in many different contexts, such as during studies, at work and as citizens. Knowledge is dynamic and constantly evolving and so needs to be examined from different perspectives. The base of my study is that there is a gap between what could and should be taught and learned in upper secondary school and the skills and knowledge required by employers. However the exploration of the boundaries between D & T education and working life may open up for important initiatives in the development of upper secondary school design and product development education.

Students studying design and product development (part of the Technology Programme) at Swedish upper secondary schools receive an introduction to the knowledge field of product development (Figure 1, A), an interdisciplinary education leading

towards both engineering and design. Students choosing this specialisation often see themselves as future students of engineering or industrial design (Figure 1, B), with upcoming careers in those professions (Figure 1, C). We can argue that the students are interested in two areas of knowledge: engineering and industrial design. There is also the possibility to enter the labour market straightaway through a fourth year in upper secondary school (Figure 1, D).

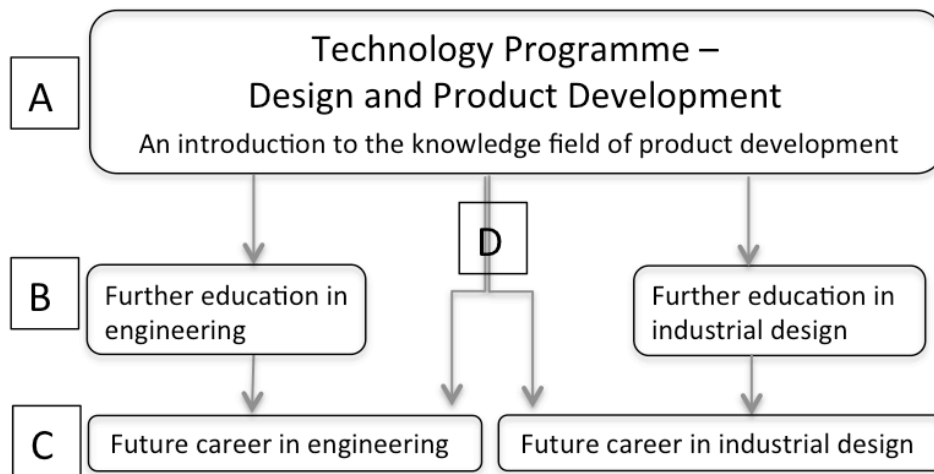


Figure 1, Model showing possible trajectories toward the engineering or industrial design professions.

In Sweden, industrial designers usually have a degree in art or design,¹ while engineers usually study engineering or science.² To qualify to teach design and product development in upper secondary schools, teachers in Sweden also commonly participate in various educational programmes depending on which subject they (want to) teach: design³ or technology.⁴ In conclusion, teachers as well as professionals have educational backgrounds in various *fields*

¹ Example of a higher educational programme for industrial designers:
<http://www.uid.umu.se/en/education/programmes/>

² Examples of higher educational programmes for engineers:
<https://www.kth.se/en/studies/master/kth/integrated-product-design/description-1.70435>
<http://www.kth.se/utbildning/program/civilingenjor/design-produktframtagning/civilingenjor-design-och-produktframtagning-300-hp-1.4118> (in Swedish)

³ Example of teacher education geared towards design:
<http://www.konstfack.se/en/Education/Teacher-Education/>

⁴ Example of teacher education geared towards technology:
<http://www.kth.se/student/kurser/program/CLGYM?l=en>

(Bourdieu, 1991; Grenfell, 2012) and in *doxa*, “the unwritten ‘rules of the game’ underlying practices within that field” (Grenfell, 2012, p. 56).

It is therefore argued that, in order to enhance both teaching and learning concerning the upper secondary school orientation *Design and Product Development*, interdisciplinary considerations need to be explored. In line with this reasoning, engineers and industrial designers in professional practice have been chosen as informants in this study.

2 Research questions

The education in *Design and Product Development* aims to provide students with knowledge useful for further studies and work within the knowledge area of product development. Figure 2 shows how teaching and learning are separated from working life. Teachers should teach their students to create and develop products (Figure 2Aa). The students' goal is to learn these abilities (Figure 2Ab). This requires a relationship between the teacher, the student and the product/artefact, as indicated by the dotted lines in Figure 2A.

In working life, engineers and industrial designers create and develop products/artefacts for a commercial market (Figure 2B). This also requires a relationship between the professionals and the products/artefacts they work with (Figure 2Bc).

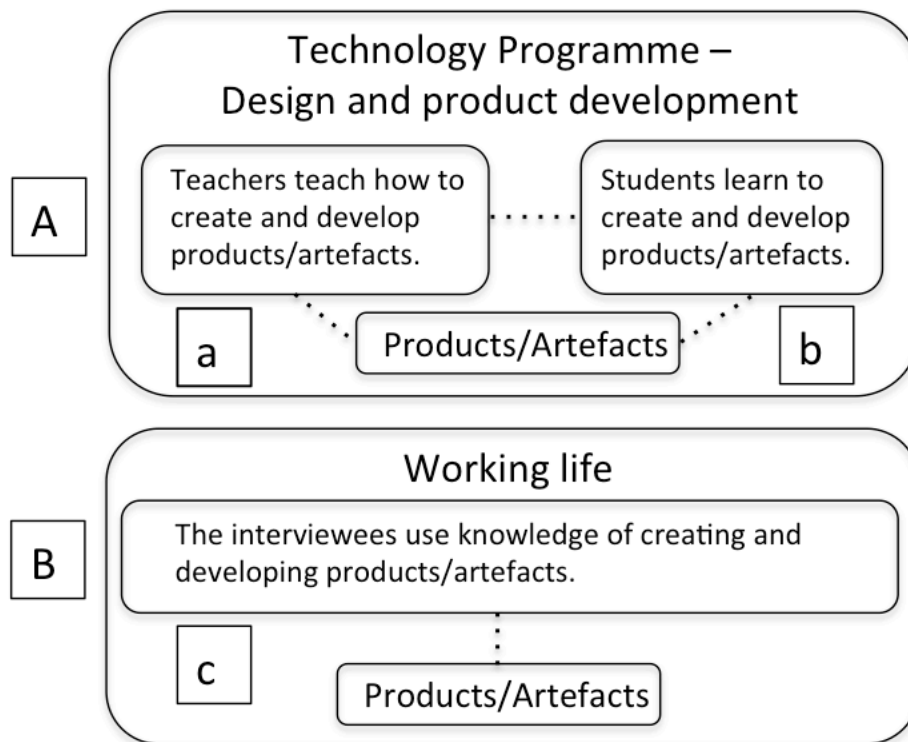


Figure 2. The relationship between humans and artefacts, and how upper secondary school activities are separated from working life.

As described in sections 4.4.1 and 4.4.2 below, product development is performed in cross-functional teams. Southee (2005) even predicts that, in the future, the engineering and design professions will blend into one. At the very least, increased interdependency between these professions is likely. In higher education, more or less successful activities have been performed to develop interdisciplinary learning and understanding between the engineering and industrial design disciplines (presented in section 4.4.2).

Upper secondary schooling in Sweden has an advantage compared to higher education in terms of interdisciplinary teaching and learning since the *Design and Product Development* orientation is focused on a knowledge field, but not towards one specific profession or discipline. It is stated in the diploma goals of the Technology Programme that the education shall “[...] give students opportunities to develop an interdisciplinary approach” (Skolverket, 2012, p. 247). This statement supports teaching that promotes interdisciplinary understanding but, in education, knowledge is divided into courses and subjects. Teachers need to interpret each syllabus and ensure that all content knowledge is mediated; this does not facilitate the development of interdisciplinary teaching. Disciplinary disagreements among teachers can also be obstacles needing to be overcome. But are there some key areas within the knowledge field of product development that may be of particular importance to be focused on in education that may also facilitate an interdisciplinary approach? In this thesis, we turn to engineers and industrial designers who are already working in product development for their views on knowledge and skills. Since artefacts play a central role in product development, the interviewees’ views on products/artefacts are also examined.

Based on the previous reasoning, a two-part overall research question is set:

(a) What thoughts do professional engineers and industrial designers express regarding necessary knowledge and skills, and (b) what relevance does this have for upper secondary school teaching of product development?

To answer this question, a study consisting of two sub-studies was conducted and the results are presented in two articles.

Sub-study 1, as described in Article 1, examines the knowledge that engineers and industrial designers consider important in their part of the process of developing products for the commercial market. The research question for sub-study 1 is:

- What skills and knowledge do professional industrial designers and engineers think are important to their work with product development?

Sub-study 2, as described in Article 2, examines the same interviewees' interpretations and valuations of artefacts, with the aim of identifying their views on, and relations to, artefacts. The research question for sub-study 2 is:

- What characteristics do engineers and industrial designers apply to eight selected artefacts?

The first part of the overall research question (*(a) What thoughts do professional engineers and industrial designers express regarding necessary knowledge and skills*) aims to understand the interviewees' views on skills and knowledge in their professions. The interviewees are considered, although having their knowledge base in different epistemologies, to be part of the same professional practice, product development, and hence to some extent share vocational culture (Höghielm, 1998, 2005).

The first sub-study (article 1), explores the interviewees' views by letting them answer predefined questions and then develop these answers. A process similar to Hartman's description of how interview guides can be used, starting with specific questions and elaborating them into issues of general character (Hartman 2004).

The questions were designed to identify the interviewees' educational backgrounds and to get their thoughts on what they learned in and what they lack from their education based on what they do in their daily work.

The choice of using the rather strict procedure of repertory grid technique in sub-study 2 (Article 2), is inspired by studies of Björklund (2008) and Lindström (2001) who examine the criteria educators use to assess creativity. The method provides possibilities to use artefacts in interview situations. Lindström (2001) uses fine metal craft works made by artisans and teacher students and Björklund (2008) lets teachers choose artefacts made by pupils during lessons in technology. The purpose of using artefacts was to examine if the interviewees' knowledge concerning artefacts could be revealed, and if so, what kind of knowledge would be expressed? Would they discuss production methods, materials, construction, styling or something else?

The second part of the overall research question *((b) what relevance does this have for upper secondary school teaching of product development)* is discussed in each article as well as in section 7. The results are reflected on for their relevance to education.

3 Thesis Outline

This thesis presents two sub-studies, one conducted as a semi-structured interview and the other using the repertory grid technique. The first study examines twelve engineers and industrial designers' thoughts about the knowledge and skills required in their work. The same interviewees' interpretations and valuations of artefacts are examined in the second sub-study. After analysis of the results, certain topics of interest for educational development are revealed. These topics concern knowledge of a general and interdisciplinary nature, visualisation abilities and valuations of artefacts' functionality.

The thesis consists of the following four parts:

Part I

Part I consists of 8 sections. Section 1 is an introduction to the research issue and so the origin of the research interest is described. The research question is presented in section 2, while section 3 offers an outline of this thesis. Section 4 concerns the background to the issue and involves presentations of the educational context in focus and an overview of other research and concepts that have influenced the ideas in this work. The methodology is described in section 5. Articles 1 and 2 are summarised in section 6. In section 7, the findings are discussed and linked to education and possible further research. Part I ends with a concluding remark in section 8.

Part II

Part II consists of the full text of both articles.

Article 1: *What You Need to Learn: Engineers' and industrial designers' views on knowledge and skills in product development.*

Published in Skogh & De Vries, 2013 (Eds.) *Technology teachers as researchers: Philosophical and empirical technology education studies in the Swedish TUFF Research School.* Sense Publisher

Article 2: *What is the function of a figurine? Can the repertory grid technique tell?*

Submitted for publication in the *International Journal of Technology and Design Education*.

Part III

Part III is a summary in Swedish.

Part IV

Part IV consists of the appendices. Appendix 1 is the questionnaire that was used as an interview guide in sub-study 1. Appendix 2, from sub-study 2, shows the 50 pairs of constructs that are the basis for the final analysis.

4 Background

This section presents an introduction to the educational context and an overview of other research studies and concepts that have influenced the ideas in this work.

4.1 The Technology Programme, an overview

In Sweden today, 91% of the population in the 25-34 age group has attained at least upper secondary education (OECD, 2013, Table A1.2a.). Upper secondary school is a non-compulsory level of schooling and there are 18 national programmes to choose from. Twelve are designed to be a trajectory to a specific vocational branch and 6 are preparatory for higher education (Skolverket, 2012). Different documents steer upper secondary schooling in Sweden, namely the Education Act, the Upper Secondary School Ordinance, the Curriculum for the upper secondary school, each programme's diploma goals and each subject's syllabus (Skolverket, 2013b). All of these documents are inter-related and are intended to create a meaningful whole (Skolverket, 2013b).

The educational context in which the research interest originates is one of the programmes preparing students for higher education: the Technology Programme. The Technology Programme covers five orientations (Figure 3; Skolverket, 2013b), one of which is *Design and Product Development*. Students who have studied *Design and Product Development* will have knowledge based on both science and art. Beside the foundation subjects, there are programme specific subjects, Physics, Chemistry and Technology. The students also take subjects specific to their chosen orientation. For *Design and Product Development*, these subjects are: CAD (Computer-aided design), Design, Art and Construction (Skolverket, 2012). These subjects indicate what is considered to be specific knowledge concerning design and product development and that the orientation is of an interdisciplinary nature.

The knowledge field of product development is central to this thesis. As the name of the *Design and Product Development* orientation indicates, design is of importance in this knowledge field, but knowledge about artefacts is also emphasised in this thesis. These matters are discussed in sections 4.2 and 4.3 and in Article 2.

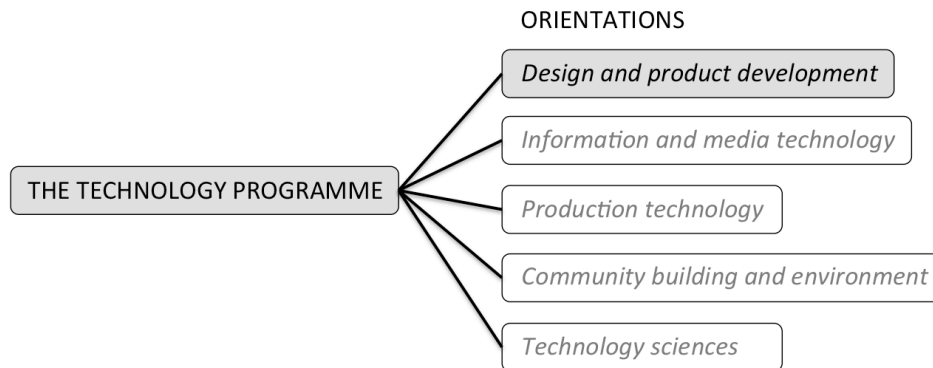


Figure 3, Programme structure of the Swedish Technology Programme. Five predefined orientations cover different knowledge fields.

The Technology Programme is of particular interest to technology education research as, over the years, it has been seen as an indicator of how society defines technology education. Higher technology education in Sweden has its roots in the development of military industry (Sundin, 1991). From the early 1960s to 1994, technology education at the upper secondary school level was a separate course programme, preparing students for higher education within engineering (Lindmark, 2009; Sweden, 1914; Göteborgs universitet, 2009). Due to rapid technological development and new demands from the labour market, the programme seemed out of date. That the programme attracted boys but not girls also contributed to decisions to allow it to become an orientation within the sciences programme (Sweden, 1988; Skolverket, 1992). However, stakeholders from industry and the research community later raised demands for pure technology education at the upper secondary school level (Sweden, 1994) and, in 1998, the Swedish National Agency for Education was commissioned by the Government to draft programme objectives and content for a new Technology

Programme. The new programme was launched in the autumn of 2000, featured new interdisciplinary subjects, and was designed to be preparatory for either higher education or working life. The focus was humans' relationships with artefacts and a more holistic approach towards technology and technological development. Education was no longer oriented towards specific technology skills or occupations (Sweden, 1998; Skolverket, 1998). This gave the schools a great deal of freedom to locally define the programme's character.

In 2011, the structure of Swedish upper secondary education experienced fundamental reform (Sweden, 2008b). The Technology Programme was changed once more, this time to be only preparatory to higher education with five predefined orientations (Figure 3; Skolverket, 2012). The reason for this was to clarify the nature of the programme and to attract more students to higher technology education (Sweden, 2008a; Skolverket, 2010).

The programme still has problems attracting girls; in the academic year 2012/13 only some 16% of the applicants were female (Skolverket, 2013c).

Design and Product Development was the orientation of the Technology Programme with the second highest number of students and about 28% of those students were women (Skolverket, 2013c). After upper secondary school, if the student wants to continue studies in product development, there are higher education programmes available in engineering and industrial design. Industrial designers often have a degree in art or design⁵ and engineers often in engineering or science⁶. Other options are Higher Vocational Education in close cooperation with industry, which offers

⁵ Example of a higher educational programme for industrial designers:
<http://www.uid.umu.se/en/education/programmes/>

⁶ Examples of higher educational programmes for engineers:
<https://www.kth.se/en/studies/master/kth/integrated-product-design/description-1.70435>
<http://www.kth.se/utbildning/program/civilingenjor/design-produktframtagning/civilingenjor-design-och-produktframtagning-300-hp-1.4118> (in Swedish)

programmes in areas where there is an explicit demand for competence.⁷ There is also the possibility in the upper secondary school to apply for a fourth year to obtain *qualified graduate from upper secondary engineering course*⁸ status. This education has emerged from requests from society, industry and other stakeholders (Sweden, 2008a, 2014).

4.2 The concept design

Design is a fuzzy concept in the Swedish language and in the Scandinavian countries it is traditionally linked to craft and artistry (Sparke, 2009; Engineering and Product Design Education Conference, 2005). In a Swedish dictionary, the word *design* is explained as a synonym to the Swedish word *formgivning*,⁹ which means to give something its shape, form and aesthetic appearance. The link to technology is not obvious. In English, the word is explained as the process of creating or constructing something according to a plan.¹⁰ Following this meaning, the word design also makes sense in an engineering or technology context in Swedish. That the meaning of the word design is changing is notable in fairly new educational programmes in higher engineering where the word design signals that the education has a specialisation where creativity and aesthetic perspectives are important.¹¹

Design was first introduced into upper secondary schools as a course within the *Technological Development* subject in the previous Technology Programme launched in 2000 (Isaksson Persson, 2010).

⁷ Examples of higher vocational education:

<https://www.yrkeshogskolan.se/Utbildningar/Teknik-och-tillverkning/CAD-konstruktor---produktutvecklingdesign-2012202501/> (in Swedish)

⁸ <http://www.skolverket.se/fran-skola-till-arbetsliv/yrkesutbildningar/2.8114/ett-fjarde-ar-for-gymnasieingenjorexamen-1.197488> (in Swedish)

⁹ http://www.svenskaakademien.se/svenska_spraket/svenska_akademiens_ordlista/saol_pa_natet/ordlista

¹⁰ <http://www.merriam-webster.com/dictionary/design>

¹¹ Examples of educational programmes in higher engineering with a design focus:

<http://www.chalmers.se/sv/utbildning/program-pa-grundniva/Sidor/Designingenjor.aspx> (in Swedish)

<http://www.chalmers.se/en/education/programmes/masters-info/Pages/Industrial-Design-Engineering.aspx>

<http://www.ltu.se/edu/program/TCTDA>

Since 2011, *Design*¹² is an individual school subject and is compulsory within the *Design and Product Development* orientation. Design can also be included in other programmes as a programme specialisation subject. In primary school, design is not an individual school subject, but design activities are integrated and represented in the syllabus of two separate subjects, namely Art and Crafts.¹³

Donald Schön describes architects, product designers and industrial engineers as classical design professionals, but he also points out that design is a broad concept: not only linked to these professions, the design process is a generic process shared by various design professions (Schön, 1987; 2003). Pei (2009) states that “the term ‘design’ is concerned with idea-based disciplines comprising of industrial design, engineering design, communication design, architecture, fashion and many others” (p.15). An industrial designer and design researcher from Sweden describes design as:

[...] design is a concept that can be used differently. [...]. [...] a capacity for action and problem solving [...] to improve our conditions. But design is also [...] a profession. You need almost to put a prefix on it, if you are talking about graphic design or industrial design or fashion design. It is a professional affiliation, which has specific knowledge about the area, like materials, manufacturing techniques, different social codes, and commercial context and so on. Common to each design profession is that it is about creating some kind of artefact.

(Interview by the author 27.03.2010).

Design-related thinking is based in the head and the hands, and knowledge about how to read and make sketches, drawings and models is essential (Cross, 2000; 2007; Kroes, 2009; Ferguson, 1978; Kimbell & Stables, 2007; Stiftelsen Svensk industridesign, 2007). Cross (2000) concludes that: “Everything around us that is not a simple untouched piece of Nature has been designed by someone” (p.3).

¹² <http://www.skolverket.se/laroplaner-amnen-och-kurser/gymnasieutbildning/gymnasieskola/sok-amnen-kurser-och-program/subject.htm?lang=sv&subjectCode=des&tos=gy> (in Swedish)

¹³ <http://www.skolverket.se>

In this thesis, design activities and thinking are seen as tools used to transform ideas from abstraction to artefacts, knowledge that various professions benefit from. It is, however, not claimed that everyone participating in product development, or in education with a focus on product development, is a designer. Rather, both engineers and industrial designers in product development need knowledge that can be classified as “design knowledge”. Whether the students of *Design and Product Development* choose a career in engineering or design, they will carry with them design knowledge.

4.3 To analyse the visual world

De Vries (2005) argues that there are experts that can read artefacts, they recognize and understand the knowledge embedded in them.

When we create and develop a product, we need besides the ability

De Vries (2005) discuss, the ability to understand and interpret an artefact, also be able to visualise an artefact before it exists.

Ferguson, (1978) calls the ability to visualise non-existing artefacts *visual or non-verbal thinking*.

Many objects of daily use have clearly been influenced by science, but their form and function, their dimensions and appearance, were determined by technologists-craftsmen, designers, inventors, and engineers-using non-scientific modes of thought. [...] The designer and the inventor, who bring elements together in new combinations, are each able to assemble and manipulate in their minds devices that as yet do not exist.

(Ferguson, 1978, p. 131)

Based on teaching experiences, to teach students with no previous experience in creating artefacts is to give them the tools to develop their visual thinking. Students need the ability to analyse the constitution of an object in order to be able to create one. At first, they have a general idea about the artefact, for example a chair, but they need to understand more about the concept “chair”. One way to do this is to examine the chair closely and understand its different parts.

Arnheim (1997) discusses the complexity of how we use perception to understand the world and states that “Visual perception is visual thinking” (p. 14). Through the interpretations of our perceptions, we generalise and produce a mental image, our own internalised understanding of what we see (Arnheim, 1997). Goldschmidt (2007) discusses how we read and write the visual world and calls this *visual literacy*. Goldschmidt (2007) claims that visual literacy is context-dependent and linked to the culture in which it is rooted.

To understand how professionals use visual literacy, the concept of professional vision needs to be recognised. Goodwin (1994) examines activities in professional practice and finds that seeing is not just a perception but also a phenomenon in social practice. He calls this *professional vision* and argues that it “consists of socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (Goodwin, 1994, p. 606). He continues and stresses that different professions interpret the same phenomena in different ways (Goodwin, 1994). When one becomes socialised into a discipline’s professional vision, language and professional vocabulary are of critical importance. Lymer (2009) examines architectural education and finds that architectural critique is one way for teachers to develop their students’ professional vision. Lymer (2009) shows how teachers of architectural education socialise students into the profession by encouraging them to learn how to *see as an architect*. During training, students are assumed to gradually develop an architectural vocabulary and presentation techniques, as well as skills in drawing and modelling. Students will learn both a visual and a rhetorical approach to architecture and, gradually, they will be socialised into the profession.

Based on the previous reasoning, it is reasonable to argue that engineers and industrial designers in product development need and use abilities to read the visual world and so possess professional vision.

4.4 Engineers and industrial designers in product development

Engineers and industrial designers involved in product development develop different aspects of artefacts. Traditionally, they receive educations based on different disciplines. Ledsome (2005) looks back in history and argues that, when engineering projects became too complex and dangerous to solve through trial and error, engineering knowledge separated from arts and crafts and became more related to science. Since that time, we have created an artificial boundary between engineering and design.

Pei (2009) accounts for engineering designers' and industrial designers' different knowledge areas in product development. He states that engineering designers and industrial designers are active in the design process of creating man-made objects, but with different foci. The industrial designer is engaged in the products' form, usability and identity. The engineering designer conducts technical activities such as finding and solving problems by applying scientific knowledge. Pei (2009) points to conflicts between engineers and designers. Even if they need to cooperate and complement each other, they still have different responsibilities, languages, codes and rules. Pei (2009) refers to these as different *object worlds*.

4.4.1 Complexity of interdisciplinary integration

In earlier times, the product development process was traditionally serial: beginning with market analysis, followed by research, product design, engineering and ending with manufacturing (Bohemia & Harman, 2008). However, many organisations have moved from sequential processes to product development in cross-functional teams where specialists from different departments collaborate during a concurrent design process (Bohemia & Harman, 2008).

Persson (2005) investigates the complexity of interdisciplinary integration in product development. Engineers' and industrial designers' processes are strongly interdependent, but are not considered as a shared process. That the two disciplines originate from different epistemologies hampers communication and interaction.

At an organisational level, the companies that Persson (2005) investigated made efforts to bridge the gap between the disciplines. In spite of these efforts, the differences between the two occupational groups hampered collaboration. Persson (2005) identified four levels of contradictions: [1] contradictions between engineers and industrial designers were institutionalised and not perceived as problems; [2] engineers' and industrial designers' differences in mind-sets, epistemologies and ideologies created perceptions of belongings to different communities; [3] project management did not support the development of common understanding, language and method since it did not provide space and time for such activities; and [4] contradictions between organisation, project and disciplines. The top management were convinced that industrial design contributed to product success, but how integration between engineers and industrial designers should be implemented was left to the practitioners.

Bridging the gap between the disciplines has not only been a focus in professional life, but also a topic for research in higher education.

4.4.2 Interdisciplinary projects in higher education

Ledsome (2005) argues that, in manufacturing today, the boundaries between engineering and design have become a barrier and to bridge this barrier is a concern for education. Furthermore, there exist some examples of projects in higher education which aim to bridge gaps and contribute to interdisciplinary learning.

Product development has become globalised and design teams may consist of different organisations that are widely spread geographically and who make use of product development in virtual settings (Bohemia & Harman, 2008). Bohemia brings this reality into higher education in cooperation with other higher education institutes in the Global Studio project, where geographically distant students form design teams and perform design tasks in virtual settings (Lauche, Bohemia, Connor, & Badke-Schaub, 2008; Bohemia, Harman & Dowell, 2009; Bohemia & Ghassan, 2012).

Rogers, Duplock, and Townson (2005) discuss product design in higher education. Such education is in a state of transformation, with technology and engineering being integrated into product design education. Rogers, Duplock and Townson (2005) present experiences from design education where students in master's level workshops develop products, including electronics. The traditional alternation between lectures and labs is replaced with full-day workshops. They state that through this method students learn context and application of knowledge rather than isolated technical details. Liem, Øritsland and Nørstebø (2005) describe how mechanical engineering students were introduced to project-based assignments with the aim of stimulating their creativity and changing their skills and mind-sets from structured to more intuitive, emotional and flexible. They worked with drawings, modelling and methods to practice visual-thinking, form and user awareness (Liem, Øritsland & Nørstebø, 2005). However, the gap between the disciplines is also present in education. Bohemia (2005) describes IDE, an interdisciplinary education derived from mechatronic engineering and industrial design, leading to a degree in industrial design engineering. Due to fundamental differences in epistemology definitions, the staff involved in such education could not mentally cross the boundaries between the disciplines (Bohemia, 2005).

These examples point towards knowledge in transformation. Southee (2005) states that engineers are associated with technology and function, while designers are associated with ideas and issues of form. Still, Southee (2005) wants to open up a debate on tomorrow's designers and engineers. Will these two professions be blended into one? Will it be designers with engineering and technology skills or engineers with additional creative and aesthetic awareness?

4.5 Knowledge in working life

To better understand knowledge in working life, Höghieli's (1998; 2005) definitions of vocational knowledge are useful. He defines the concept of *vocational knowledge* without it being directed towards a specific occupation. Höghieli (1998; 2005) argues that vocational knowledge is closely related to the concepts of vocational culture, vocational practice and vocational competence. The vocational culture is based on the traditions in a particular vocation and on mediated collective experiences. The vocational culture is normative; it shapes vocational practice and it defines to some extent what counts as vocational knowledge. Vocational practice is the rules and procedures that are used in a certain vocation.

In addition to vocational knowledge, a more general and interdisciplinary nature of knowledge could be identified in working life. Definitions differ between countries and contexts. Examples of concepts commonly used to describe this additional knowledge are "key skills", "key qualifications", "key competences" and "new basic skills" (Kämäräinen, 2002). In this thesis, the term *key qualifications* is used to describe these abilities. Key qualifications are associated with a person's capacity to work with others, to deal with new situations, to take initiatives, to be socially competent, to be flexible, communicative and analytical, and to solve problems, as well as a person's knowledge of languages and computing (Höghieli, 2005; Höjlund, Göhl, & Hultqvist, 2005; Kämäräinen, 2002). For more

information about how *knowledge in working life* is defined in this thesis, please read the *Theoretical Framework* in Article 1.

5 Method

The following sections summarise the methodological aspects of this thesis, which are described in more detail in the two separate articles.

5.1 The overall research process

In this qualitative research (Alvesson & Sköldbberg, 1994; Hartman, 2004; Marshall & Rossman, 2006; Patel & Davidson, 2003; Williams & May, 1996), the purpose is to obtain the interviewees' own ideas about important skills and knowledge in their respective occupations as engineers and industrial designers. The goal is to identify perspectives on knowledge in product development that related education could benefit from. With this as an overall goal, the study was conducted as a semi-structured interview (Hartman, 2004; Patel & Davidson, 2003) consisting of two sub-studies. The first sub-study use the questionnaire in Appendix 1 as an interview guide, while the second is conducted using the *repertory grid technique* (RGT). All the interviews save for one were recorded. In the case of the one interviewee who found the recording process uncomfortable, notes were taken instead. All the interviews but one were conducted at the interviewees' work places.

5.1.1 The interviewees

Twelve career-active industrial designers and engineers have been interviewed; five female and two male industrial designers as well as three female and two male engineers. They all work in the manufacturing industry and their experience within the profession varies from just a few years up to thirty years. They all work in different companies and all but one interview was conducted at their respective workplaces. When the interviewees discuss their experiences from education, they refer mainly to the education they consider led to the profession.

The industrial designers have the most homogeneous educational background. Technology or science education was the most common education on upper secondary school level for the majority of the interviewees. They have all completed higher education and been awarded degrees in design or art. One has an additional degree in engineering. Some of them are employees and some are entrepreneurs with or without employees of their own.

The engineers have a more diverse educational background even though all attended technology or science education at upper secondary school level. Three engineers have completed four-year technology education at upper secondary school level and additional courses at their respective workplaces. One engineer has a master's degree and one has a doctoral degree in science. All of the engineers work in consulting businesses.

5.2 Collection of data

5.2.1 Collection of data, sub-study 1

The interviews are based on open-ended questions from a questionnaire (Appendix 1) used by the interviewer as a guide (Hartman, 2004; Patel & Davidson, 2003; Sweden, 2010). The questionnaire was used in such a way that the interviewer read out the questions to the interviewee. Questions 1 to 4 of the questionnaire (Appendix 1) provide information about the interviewees' educational background. Questions 5 to 7 highlight their reasons for becoming engineers or industrial designers. Questions 8 to 13 focus on the interviewees' views on what skills and knowledge they consider to be of professional significance. The interviews were recorded (save for one) and the interviewer also took notes.

The interviewees discussed issues freely and the questions were not always answered in numerical order. The interviewer also asked follow-up questions as in the following example:

Interviewer: Can you rank the three most important skills or competencies for practitioners of your profession? If you look beyond yourself.

Interviewee: Well, to get people to work together towards a common solution or a common goal. You should absolutely not do everything yourself, it's not possible. [...]. The thing is to get everyone to work together and to be the one that holds everything together.

Interviewer: Do you think that people understand that this is how you work as a higher engineer? That you...

Interviewee: Nah they probably think you're sitting at your desk (alone, author's note) [...]. As you almost never do, you're in meetings, always, in one form or another, [...]. Discuss money [Laughter]. Or a new complete proposal; this is how we should do this project and then, see the management and tell them that this is the cost and this is the time it takes. So keep time, technology and money together. Follow up on schedules and such is also very important.

Interview with Engineer O8, 01.10.2009

The recordings were transcribed and the transcripts categorised (Holsti, 1976; Jankowicz, 2004). The interviewees' answers to questions 8, 9, 10, 12 and 13 of the questionnaire (Appendix 1) were found to be of particular interest in the context of this study and so became the basis for the initial categorisation. For more information, please read Article 1.

5.2.2 Collection of data, sub-study 2

The aim of sub-study 2 is to examine how engineers and industrial designers interpret artefacts. Artefacts are of significance in product development and in design and product development education and because of this of particular interest to this study. The repertory grid technique (RGT) was chosen because of its potential to include artefacts (Björklund, 2008; Jankowicz, 2004; Jordan & Persson, 2007; Lindström 2001; Persson, Hiort af Ornäs & Jordan, 2007) and because of its procedure, which lets the interviewees take an active role in the interview situation and reduces the influence of the

interviewer. The decision to design the interview in this way was an interest to examine if the interviewees' interpretations could reveal their knowledge of artefacts and whether there were differences and/or similarities in their answers.

The method derives from George Kelly's work and is based on his *theory of personal constructs* (Fransella, Bell & Bannister, 2004; Jankowicz, 2004; Kelly, 1963). Although it has a quantitative structure (Jankowicz, 2004), RGT is primarily a qualitative method, the main purpose of which is to understand other people.

Kelly claims that we base our worldview on how we construe our experiences. When we interpret our world, we use multi-dimensional attributes, which Kelly calls *constructs* (Kelly, 1963). Fransella, Bell and Bannister (2004) summarise Kelly's view on how we construe the world as "[...] we never affirm anything without simultaneously denying something" (Fransella, Bell & Bannister, 2004, p. 7). The construct narrates two things about how we define a certain topic: what we consider to be characteristics and what we think is opposed to or contrasts with this. This renders constructs bipolar.

The procedure of the RGT results in a number of two-dimensional constructs. The RGT is a method used to elicit constructs concerning a certain topic and in such a way as to understand how a person perceives the world. For more information, please read Article 2.

The interviewer has selected eight consumer products representing a variety of materials, forms, expressions and functions. Six to twelve elements (not necessarily artefacts) are recommended to use in the interview situation (Jankowicz, 2004). Three artefacts at a time were presented to the interviewee. The interviewee then describes characteristics that two of the objects share but that the third does not. The third object's opposite characteristic is also described. These contrasting characteristics are the two dimensions of a *construct*.

The constructs are noted in a grid sheet. From the interviews, 12 grids including 119 constructs have been elicited. A rating procedure makes it possible to compare an interviewee's constructs. If two constructs have similar ratings, they also have a similar meaning to the interviewee. The ratings and relationships within a grid can be analysed with a variety of methods (Jankowicz, 2004).

Four objects often resulted in distinctive ratings. To examine whether there were similarities in how the interviewees described and valued these objects, a comparison procedure was developed as such a method is not provided by RGT. The analysis process is fully described in Article 2.

5.3 Ethical considerations

The guidelines of the Swedish Research Council, Vetenskapsrådet (Gustafsson, Hermerén & Petersson, 2005), have been followed.

Work-active engineers and industrial designers are busy and so it was hard to find participants for the study. The participants work in two cities in Sweden. Both females and males are represented, as well as different ages and years of experiences in the profession. The interviewees have been informed about the purpose of the interview and the research interest and have agreed to participate.

6 Summary of Articles

6.1 Article 1

What you need to learn: Engineers' and industrial designers' views on knowledge and skills in product development

Skogh & De Vries, 2013 (Eds.) *Technology teachers as researchers: Philosophical and empirical technology education studies in the Swedish TUFF Research School*. Sense Publisher

Both engineers and industrial designers play important roles in product development. Are there common knowledge and skills that professional engineers and industrial designers consider important in their work with product development? If so, to what extent does technology education in upper secondary schools reflect and prepare students for the demands of working life?

The research question that is explored here is:

- What skills and knowledge do professional industrial designers and engineers think are important to their work with product development?

The findings presented in this article are based on the answers obtained from interviews with engineers and industrial designers, all of whom work in product development.

The interviews are semi-structured in the sense that open-ended questions from a questionnaire were used and discussed freely with follow-up questions from the interviewer (Appendix 1). The answers to questions 8, 9, 10, 12 and 13 have been categorised in the search for keywords and themes, and form the basis for further analysis (Appendix 1).

Questions 8 and 9 (Appendix 1) focus on education: what the interviewees think they have learned and what they lack from their education. The results show that both engineers and industrial

designers consider that they learned their basic knowledge and skills in education and also gained a first insight or introduction to the “spirit” of the profession.

According to the engineers, the characteristic of being an engineer, the “spirit” of the profession, is to be curious, work with problem solving and understand technology in a practical way. The industrial designers also highlight curiosity as well as abilities to understand, communicate and visualise form and to be creative within a timeframe. What the interviewees consider to be basic knowledge and skills differs between the two occupational groups. Examples of what the engineers refer to are mathematics, design engineering, technical drawing. The industrial designers, on the other hand, refer to techniques for visualisation such as sketching and modelling.

The interviewees lack training in teamwork from their formal education, from upper secondary school or higher education depending on which education they refer to as preparatory to the profession. The engineers also lack learning about leadership (Question 9, Appendix 1).

Questions 10, 12 and 13 (Appendix 1) are about the profession: what the interviewees do, what they learned and what they think is important in their profession and daily work. The answers to question 10, what the interviewees have learned in professional practice which they did not learn in education, concern skills and knowledge that are needed when solving specific vocational tasks and can be described as basic developed knowledge or specific vocational knowledge. Moreover, both occupational groups learned about teamwork in professional practice and the engineers also learned about leadership.

Question 12 concerns what the interviewees frequently do. The engineers’ answers concern use of specific vocational knowledge and skills as well as engagement in leadership, teamwork and design

engineering. The industrial designers frequently use specific vocational knowledge and skills and are engaged in teamwork.

When the interviewees are asked what they consider important to practitioners in their professions (Question 13, Appendix 1), they give answers that concern the same issues as in question 12, but both occupational groups also refer to the “spirit” or knowing the core of the profession.

6.1.1 Summary of results in relation to research question in Article 1

What skills and knowledge do professional industrial designers and engineers think are important to their work with product development?

In their formal education, the interviewees gained their first insight into what it means to be an engineer or industrial designer along with *basic knowledge and skills*. In their working life, the interviewees have deepened their basic knowledge as well as added new insight and thereby gained *specific vocational knowledge and skills* necessary to perform the work tasks. Engineers and industrial designers hold and use different specific vocational knowledge and skills and develop different aspects of products. However, both occupational groups have knowledge of *visualisation* with digital models. The tool the interviewees refer to when discussing development of digital models is CAD. The actual software that the interviewees use differs, but common feature of the CAD tools is an interface with a three-dimensional space in which three-dimensional digital objects can be created. The interviewees’ abilities are not limited to skills in using software; they can also interpret the model on screen and manipulate it so the end result can be used to produce a final product that keeps the set requirements. They describe this ability with a verb, *to CAD*

Both engineers and industrial designers work in teams. They have specific positions in the team, but to meet the goal for the team, to produce a final product, it is not enough to possess specific

vocational knowledge and skills and solve specific vocational tasks. The interviewees also interact; they collaborate, compromise, communicate, and lead. These abilities can be classified as key qualifications (Kämäräinen, 2002). In this thesis, we summarise these abilities and refer to them as *to act within the team*. This ability is necessary for the interviewees to be able to navigate and position themselves in the team.

The interviewees in this study value the basic knowledge and skills they received from their education. When it comes to abilities included in *to act within the team*, education was seldom the source of learning. The interviewees have different opinions on how they have learned this. Some emphasize social activities or collaboration with other students outside the regular training, other refer to learning in working life, by working on projects with colleagues and clients.

The results presented in this thesis expand Höghielm's (1998; 2005) definitions of vocational knowledge by describing how specific vocational knowledge and key qualifications are intertwined. In education, we can learn from these results and so should strive to include activities in which students are given the opportunity to develop the ability *to act within the team* to prepare them for further studies and working life.

6.2 Article 2

What is the function of a figurine? Can the repertory grid technique tell?

Submitted for publication in the *International Journal of Technology and Design Education*.

This article presents the results of a qualitative study of engineers' and industrial designers' interpretations of artefacts. De Vries (2005) emphasises that there are experts that have special knowledge about artefacts; they can construe artefacts and recognise and understand the knowledge that made them what they are. In this study, engineers and industrial designers are considered to possess such

knowledge and it is this knowledge that is central in education concerning design and product development.

The research interest that is the foundation of this study emerged from experiences of teaching design and product development at the Technology Programme in a Swedish upper secondary school. The question is, can we – through artefacts – find out how professionals interpret artefacts and thus learn knowledge of relevance to education concerning design and product development?

Answers are sought among professional engineers and industrial designers. Possible applications of the findings on design and product development education in upper secondary schools are included. Awareness of the differences between these arenas, however, does not constitute an obstacle to the exploration of professionals' views and thoughts.

The research question explored in this article is:

- What characteristics do engineers and industrial designers apply to eight selected artefacts?

The method used is the repertory grid technique (RGT) (Fransella, Bell & Bannister, 2004; Jankowicz, 2004; Kelly, 1963). The choice of RGT should be seen in the light of the possibilities it provides for the interviewees to study, reflect and discuss artefacts. The method also reduces the influence of the interviewer and lets the interviewees describe the topic in focus in their own words.

6.2.1 The elicitation procedure

The elicitation procedure of constructs in this study is as follow: eight objects are selected by the interviewer and presented to the interviewees as representations of the topic *products*. Representations of a topic are called elements and in this case they are a selection of consumer products that represent a variety of materials, forms, expressions and functions. The elements are: a bicycle helmet, a

Christmas tree ornament, a watering can, revolving punch pliers, some cutlery, a cigar box, a multiple socket and a reindeer figurine.

The main criterion for the selection of items was that the objects would be perceived as “simple” and easy to describe. The decision to use pre-selected elements should also be seen in light of a wish to compare the interviewee’s constructs and, through this, try a variant of RGT.

The interviewer presents a trio of elements to the interviewee. The interviewee chooses two of these elements that have shared characteristics. The interviewee also describes the opposing characteristic represented by the third element and thereby completes the elicitation of a construct. The interviewer writes down the characteristic of the two elements on the left side of a grid sheet and the characteristic of the third on the right side; these are the construct’s two contrasting dimensions or poles.

The next step for the interviewee is to compare the other five elements’ characteristics with this construct. This comparison is made, as ratings where the value of 1 represents the construct’s left pole and 5 the right. If an element possesses characteristics equally from both poles, it is rated as 3. It is also possible to rate an element as 2 and 4 if the element’s characteristics do not fully coincide with the dimensions of the constructs. A new trio is then shown to the interviewee and the procedure of eliciting constructs and rating artefacts is repeated. The purpose is to elicit as many different constructs as possible per interviewee per element; about eight to twelve is the amount to aim for (Jankowicz, 2004).

Twelve grids with a total of 119 constructs have been elicited in this study and are the basis for further analysis. *Eyeball analysis* and *cluster analysis* are used as a first step to examine the interviewees’ constructs. During the analysis procedure, it became clear that certain elements stood out and were often high or low rated. Were there similarities in how the interviewees described and valued certain elements? RGT does not provide a comparison method

between grids (Jankowich, 2004), but the use of pre-selected elements made it possible to compare the interviewees' constructs.

6.2.2 The comparison procedure

The comparison procedure developed in this study is as follows: Constructs that have similar ratings have, according to RGT, similar meaning to an interviewee (Jankowich, 2004). Pairs of such constructs with a match in ratings from 80% are chosen and the outcome is a list of 66 pairs of constructs, with all interviewees represented. The ratings are converted so the values of a construct's left pole can be compared with the value of the construct's right pole. Some 50 of the 66 pairs of constructs involve the reindeer figurine and/or the Christmas tree ornament in contrast with the revolving punch pliers and/or the multiple socket. After a review of these constructs, words such as "decoration", "ornament", "aesthetics" and "function" are found to occur frequently. To verify this, all 119 constructs are once more considered in an additional analysis inspired by *content analysis* (Holsti, 1976; Jankowicz, 2004).

After further analysis, it is found that words such as "decoration", "aesthetics", "ornament" and "function" more often occur in pairs of constructs that have high similarities in ratings than in other constructs. We also know that, among these pairs of constructs, the reindeer figurine and the Christmas tree ornament represent one end of a dichotomy where the revolving punch pliers and the multiple socket represent the other end. Hence, they represent opposing characteristics. These characteristics are described by the word or sentences linked to the constructs' poles. After a compilation of the constructs regarding these four objects and with support from the interviewees' citations, we get a rich picture of the interviewees' valuations of the artefacts.

6.2.3 Summary of results in relation to research question in Article 2

Some methodological reflections regarding *supplied artefacts*, *time*, *ratings* and *the comparison procedure* have been made. *Supplied artefacts*

increase the researcher's influence (Yorke, 1978). Additionally, the selection of artefacts affects the results, since different objects had elicited other constructs. It can also be argued that the selection of artefacts is too wide and that the interviewees discuss product categories rather than specific products. But the focus in this study has been on how the interviewees construe and discuss the objects rather than the objects being of a certain type or category. How the interviewees interpreted these specific objects is now known, even if the interviewer provided them.

Time is an aspect to consider when using the RGT as it is quite a time consuming method. Jankowicz (2004) states that it usually takes 30 to 60 minutes to elicit and rate 6 to 12 constructs. After 60 minutes, both interviewee and interviewer are drained (Jankowicz, 2004). For the interviewees in this study, it took about 30-45 minutes to elicit 10 constructs each, so spending more time on eliciting constructs had not been fruitful. However, time is also an issue when using other interview techniques (Pei, 2009).

Ratings are primarily used in this study to verify patterns that were shown in the discussions during the interviews and in the eyeball analysis. Initially, the challenge was to teach the interviewees the elicitation procedure. It might feel right to value clearly negative-positive constructs from left to right, in other words letting negative characteristic represent the left pole, hence value 1, and the positive characteristic represent the right pole, so value 5 (Jankowicz, 2004). This happened in this study and a couple of ratings needed correction after checking the recordings.

A *strategy for comparing* data from the grids has been developed to verify the patterns that have been observed in the initial analysis. Constructs with similar ratings have similar meaning to the interviewee and such constructs have been further analysed and compared. The supplied elements facilitated comparison between data from different grids.

What characteristics do engineers and industrial designers apply to eight selected artefacts?

When comparing grids in search of patterns, some details may be lost (Jankowicz, 2004), but in this study it is the collective description that provides the complete picture of the interviewees' valuation of the artefacts.

The results show how the interviewees apply certain characteristics to four of the artefacts, namely the reindeer figurine, the Christmas tree ornament, the revolving punch pliers and the multiple socket. We can argue that the interviewees discuss the *functional nature* of these artefacts (De Vries, 2005). The reindeer figurine and the Christmas tree ornament are considered to be without function and associated with words such as “not useful”, “appearance”, “personal satisfaction”, “social behaviour”, “soft”, “sentimental value” and “home environment” as well as with words such as “aesthetics” and “decoration”. In the results, this characteristic is called the *decorative function*. The revolving punch pliers and the multiple socket, on the other hand, are only functional. They are described as “complicated” and “useful tools” and associated with “technology”, “smartness”, and “protection”. Based on Kelly's (1963) reasoning, the interviewees' constructs can be seen as cultural expressions that describe the interviewees' interpretations of the artefacts' functional nature. Using the *dualistic gender metaphors* (Wajcman, 2004) helps us to understand this cultural phenomenon; the decorative function is placed in another sphere to the functions of the revolving punch pliers and the multiple socket. Discussed in the governing documents for the Technology Programme are the relationships between gender and technology (Skolverket, 2012; 2013b). The text emphasises that education must take as its starting point the experiences of women and men in relation to the technology area and take into account traditions and attitudes that affect our view of what is considered masculine and feminine. That we project values of products in terms of gender is previously described in the literature (Kirkham, 1996). The results of

this study show that the interviewees project cultural values, linked to functionality, onto products. We suggest that the governing documents should problematize our relationships to artefacts more, not just in terms of gender. To reflect the results of this study in education, the study as described here could be repeated within an educational context with teachers and students to get a richer picture of how we value artefacts compared to industrial designers and engineers.

7 Discussion

In this section, the results of Articles 1 and 2 are discussed as well as reflected on in the steering documents for upper secondary schools and the diploma goals of the Technology Programme. The results are also discussed from the perspective of how they contribute to increased knowledge and further research.

Once more, the overall research question to consider is:

(a) What thoughts do professional engineers and industrial designers express regarding necessary knowledge and skills, and (b) what relevance does this have for upper secondary school teaching of product development?

Two topics, *To act within the team* and *To CAD* (Figure 4), are of significance to the interviewed engineers and industrial designers in their working lives. These two topics are related to the research question in sub-study 1. Another topic, *Valuations of artefacts* (Figure 4), is identified in sub-study 2 and further analysed. The result of this analysis demonstrates how the interviewees interpret and discuss artefacts' functionality linked to cultural values.



Figure 4. The topics concerning important knowledge and skills in product development applicable to upper secondary education.

The first topic, *To act within the team*, concerns activities in product development that both the engineers and industrial designers consider important. The second, *To CAD*, is also considered important for both occupational groups even though engineers and industrial designers work with different aspects of products and use different soft ware. The result of sub-study 2 was expected to give the interviewees' views on artefacts' properties and production methods. Instead it demonstrated how the interviewees interpret

and discuss four of the artefacts' functionality linked to cultural values. The coherence between the occupational groups was great and resulted in the third topic, *Valuations of artefacts*. Due to limited sample this thesis does not claim to generate knowledge of a general nature but the three topics presented here are considered suitable to work with in technology education on upper secondary school level geared towards design and product development. All three topics will be further discussed.

7.1 To act within the team

The first sub-study conducted as a semi-structured interview (Article 1) examines the research question: *What skills and knowledge do professional industrial designers and engineers think are important to their work with product development?*

The results show that the interviewees appreciate the basic knowledge that education has provided, including a first insight into what it is like to be an engineer or industrial designer. The interviewees also emphasise the importance of holding specific vocational knowledge. For engineers it is, for example, mathematics, problem solving or matters linked to design engineering. For industrial designers sketching and modelling are important competences. Beside this, the importance of holding knowledge of a more general and interdisciplinary nature is stressed. The interviewees collaborate, compromise, communicate and more. In this thesis, this ability is called *to act within the team*.

This knowledge is *intertwined* with specific vocational knowledge, knowledge needed to solve everyday tasks. The steering documents for upper secondary schooling in Sweden are vague concerning how students shall achieve knowledge of a generic character. These are defined in a general way in the curriculum for upper secondary schools: "Students should develop their ability to take initiatives and responsibility, and to work both independently and together with others" (Skolverket, 2013b, p. 6) or "Developments in working life mean, inter alia, that traditional boundaries between different

vocational areas need to be reduced, and that demands are imposed on awareness of not only one's own competence, but also that of others" (Skolverket, 2013b, p. 6). The National Agency for Education also refers to the EU's recommendation on key competences (Skolverket, 2012, p. 13; European Union, 2007). They continue, "[...] foundation subjects in the upper secondary school should interact with subjects typical of a programme, and it is through specialisation in the latter that students develop, both as citizens and as individuals" (Skolverket, 2012, p. 13).

The diploma goals of the Technology Programme are more specific: "[...] education should give students knowledge about and skills in cooperating with others" and education shall "[...] give knowledge of project work, and skills in working in projects [...]" (Skolverket, 2012, p. 247).

The interviewees in this thesis lack training in teamwork from their formal education and have different opinions on how they have later learned this. Some emphasise social activities or collaboration with other students outside regular training, others refer to learning in working life by working on projects with colleagues and clients. Although the steering documents promote skills of a generic character, there is a lack of research on how, in practice, schooling influences the development of these abilities (Skolverket, 2013a).

The Technology Programme could be an arena to study how schooling influences the development of such abilities since the diploma goals state that education shall provide knowledge about, and skills in, cooperating and project work (Skolverket, 2012). Questions to be addressed could concern teachers' approaches to collaboration, communication and leadership. What methods and strategies are used? What do students think they learn when cooperating in projects? RGT can be used to examine both teachers' and students' ideas about what collaboration and project work is.

7.2 To CAD

The results in Article 1 show that CAD is an important tool for visualisation. The interviewees appreciate the knowledge on how to understand and develop products with the CAD tool. They generally describe this ability with a verb, as does industrial designer O5 in the following quotation:

O5: I visualise. [...] first, I thought to say that I CAD and make sketches, but it's just a kind of tool to get the...

Interviewer: So, it is part of visualisation?

O5: It's part of visualisation, [...] CAD and sketches and models [...].

Interview with industrial designer O5, 23.03.2009, p.5

In this thesis, the ability is called *to CAD*. This knowledge is not limited to skills with software, but instead includes the ability to develop a digital model that represents the end product and holds quality requirements.

There are different opinions among the interviewees about how to become proficient in CAD. One industrial designer believes that young people, who only work in CAD and therefore lack experience of fixing and building things, are missing important insights. One engineer thinks it is a disposition:

Interviewer: You learned CAD at work?

O1: At work, yes, yes. I felt that it was real fun. Different people have ... some have CAD genes and others do not, and I have a CAD gene.

Interview with engineer O1, 01.10.2009, p.3

When visualising with CAD tools, understanding the relationship between the model on screen and a not yet existing end product is also needed. An example of this is the following quote in which engineer O1 discusses how the model on screen will differ from the final result:

Exactly, because you must understand this [...] if you say that something should be 11.3 mm, it will not be 11.3 mm. It will be 11.3 mm plus or minus something. In

CAD, it will be 11.3000000000, but in reality it will not be like that, [...]. So it does not become perfect in reality just because it is absolutely perfect in CAD.

Interview with engineer O1, 01.10.2009, p.7

The results show that visualisation with CAD tools is a complex ability and important to the interviewees in their work. The diploma goals for the Technology Programme do not discuss what constitute visualisation. In *Design and Product Development*, the subjects of CAD (Computer-aided design), Art, Construction and Design are subjects specific to the orientation. In the diploma goals it is stated: “The orientation includes the subjects CAD, art, construction and design, which gives the orientation a distinctive technical profile. The subject art provides the foundations for colour and form, whilst CAD provides the technical tool in the design process” (Skolverket, 2012, p. 254). We can guess that the content of these subjects helps students to learn visualisation abilities. As industrial designer O5 clarifies, CAD is a tool but, when she uses CAD together with sketching, she visualises. Is it possible, in design and product development education, to examine how we learn visualisation with CAD tools?

Knorr Cetina and Bruegger (2002) examine financial traders’ relationships with computer screens. The screen opens up and visualises the financial market for the traders. They get access to knowledge about prices, deals and so on; they are also connected and a part of the market through the computer screen. The financial market on the screen is a construction of knowledge, an *epistemic object*, not confined to a particular group of people or to certain artefacts. Nerland (2008) describes epistemic objects as tools that can be used at once, but that are also constantly evolving.

As result of this argument, it can be questioned; if CAD models are regarded as epistemic objects, is it possible to learn more about the ability *to CAD*?

7.3 Valuations of artefacts

The second sub-study conducted with the *repertory grid technique* (RGT) (Article 2) examines the research question: *What characteristics do engineers and industrial designers apply to eight selected artefacts?*

The results show that the interviewees value artefacts' functionality in similar ways. The artefacts with a distinct decorative purpose (the reindeer figurine and the Christmas tree ornament) are not considered useful or to possess functionality. Industrial designer O11 summarises this feature when describing the reindeer figurine: *"It has no function; it has only an aesthetic function [...]."* In this thesis, this feature is called *the decorative function*. The decorative function is associated with appearance, aesthetics and personal expression. In contrast to the decorative function is the function that is represented by the revolving punch pliers and the multiple socket. These objects are described as complicated, useful tools and associated with technology, smartness, and protection.

The interviewees' associations have similarities with the dualistic gender metaphors (Wajcman, 2004); the interviewees put aesthetic functions in a different sphere than functionality and usefulness. According to Kelly (1963), we belong to the same cultural group as those who interpret the world around us in a similar way to how we do. Based on this reasoning, the interviewees' interpretations of the artefacts can be seen as a cultural expression. The governing documents problematize to some extent the relationship between technology and gender "Technology is in itself gender neutral, but its use is not always neutral" (Skolverket, 2013b, p. 249). Besides this commentary, the steering documents do not comment on our relations to or valuations of technology or artefacts. Based on the results in this thesis, we wish the steering documents to problematize our relationship to artefacts more, not only in terms of gender. If our relationships with artefacts were highlighted in the steering documents, there would be an incentive to deepen the discussion in the classrooms about how artefacts affect both our lives and society today.

As others have pointed out, our relations to, and interactions with, artefacts have an impact on our lives (Bechy, 2003; Knorr-Cetina & Bruegger, 2002; Knorr-Cetina & Savigny, 2001; Latour, 1999; Kirkham, 1996; Säljö & Linderöth, 2002). The results in this thesis show that the interviewees are projecting cultural values linked to the products' functions. Based on the results in this thesis, further research can provide understanding about how artefacts and their functionality are valued in educational settings. How do teachers value artefacts' functional nature? Do their previous education and work experiences have importance? In comparison, how do teachers working within various levels of the educational system value artefacts' functionality? How do students value artefacts' functional nature? Do their valuations change over the course of their education? We can examine these questions by using the methods described here: semi-structured interviews and RGT. To take the analysis of functionality further, the philosophical work of Dooyeweerd (Bergvall-Kåreborn, 2001; Clouser, 2010; De Vries, 2005) can be considered. With more understanding of how we value artefacts' functionality, we can expand the critical discussion about technology, not only in terms of gender.

8 Concluding remarks

The arenas of education and working life are interconnected and even if students studying design and product development at upper secondary school need more education to become engineers and industrial designers highlight the results in this thesis matters for education on lower levels to consider. Based on the result presented here, project and teamwork should be focused as an important element in D&T education. It is also seen that it is important to practice this knowledge on real examples relevant for product development.

The purpose of the CAD model in product development is to visualise a product that does not yet exist. The interviewees understand relationships between a CAD model on screen and the final product. This can be a focus also in education. Training in developing digital models into prototypes, crafted or 3D-printed, can be one way to understand this.

The interviewees associate artefacts' functionality with certain characteristics. In education students should learn that we are not neutral in our relations to products and other artefacts. We see a need for discussing artefacts from different perspectives such as sustainability, usability, identity and so on.

8.1 Further research

In this thesis, we interview engineers and industrial designers who are working in product development. Based on the results from this study, D&T education is the next arena for further research.

The results show that specific knowledge for engineers and industrial designers are intertwined with key qualifications like for example collaboration, communication and leadership. Although the steering documents promote skills of a generic character, there is a lack of research on how, in practice, schooling influences the development of these abilities (Skolverket, 2013a). Questions to be

addressed in these matters can concern both teaching and learning. What are teachers' approaches and what methods and strategies are used in D&T education to promote such abilities? From a student perspective, what do students think they learn when they take part in activities intended to promote this? *Repertory grid technique* can be a possible method to explore both teachers' and students' ideas.

Another area for further research is to study three-dimensional digital modelling as a source for teaching and learning. The CAD model on screen represent something that is not yet produced, and this representation change during the development process and must be understood by both teacher and student. An *epistemic object* is a tool that can be used at once, but that are also constantly evolving (Nerland, 2008). If CAD models are regarded as epistemic objects is it possible to learn about the ability to CAD? One way to approach this is to use repertory grid technique to investigate teachers' and students' ideas about CAD models.

The interviewed engineers and industrial designers use strategies and methods derived from different disciplines but value artefacts' functional nature in similar ways. We do not know if these valuations are specific to engineers and industrial designers, but we do know that the interviewees are not neutral in their attitudes towards them. Are these patterns repeated in education? Repertory grid technique can be used to study valuations of artefacts in education in a similar way as in this study. To deepen the analysis, Dooyeweerd's ideas about artefacts' functionality (Bergvall-Kåreborn, 2001; Clouser, 2010; De Vries, 2005) can be regarded. An artefact, unlike a natural thing (Clouser, 2010), needs to be considered based on its intended purpose. Therefore, the artefact's functionality needs to be considered both for its qualities as a subject and for its qualities as an object in the context it serves (Clouser, 2010; De Vries, 2005). Dooyeweerd's perspective opens up for further analysis and demonstrates the complexity of artefacts' functionality.

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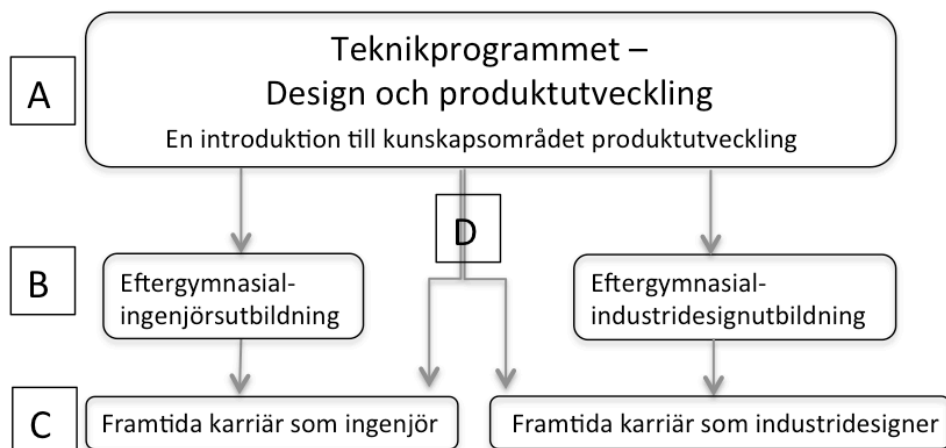
PART III SUMMARY IN SWEDISH

ATT ÖVERBRYGGA GRÄNSERNA MELLAN TEKNIKUTBILDNING OCH ARBETSLIV:

En studie av epistemologiska uppfattningar bland yrkesverksamma inom fältet produktutveckling

1 Introduktion

Forskningsfrågan i denna avhandling har sitt ursprung i lärarpraktiken men söker svar utanför denna arena bland ingenjörer och industridesigners. Utbildningsområdet i fokus är Teknikprogrammets inriktning *design och produktutveckling* inom svenska gymnasieskolan. I gymnasiet får eleverna en introduktion till kunskapsområdet produktutveckling (Figur 1, A), en tvärvetenskaplig utbildning inom både ingenjör- och designområdet. Erfarenhetsmässigt har det visat sig att eleverna ofta ser sig som framtida ingenjör- eller industridesignstudenter (Figur 1, B) med kommande karriärer inom dessa yrken (Figur 1, C). Vi kan, med viss säkerhet hävda, att eleverna i denna inriktning är intresserade av två kunskapsområden, ingenjörsvetenskap och industridesign. Det kan även påpekas att det numer finns möjlighet för eleverna att komma in på arbetsmarknaden direkt genom ett fjärde året i gymnasiet (Figur 1, D).



Figur 1, Modell som visar möjliga banor mot ingenjör- och industri-designyrket.

I Sverige har industridesigners ofta en examen inom konst eller design¹⁸ medan ingenjörer har en ingenjörsexamen eller en examen inom naturvetenskap¹⁹. Även lärare på gymnasieskolan som undervisar inom kunskapsområdet design och produktutveckling kan ha utbildningar från olika discipliner beroende på om de undervisar i design²⁰ eller teknik²¹. I sammanfattning kan sägas att lärare likväl som yrkesverksamma har utbildningsbakgrund inom olika *fält* (Bourdieu 1991; Grenfell, 2012) och i *doxa*, “the unwritten ‘rules of the game’ underlying practices within that field” (Grenfell, 2012, s 56). Med tidigare resonemang i åtanke kan det hävdas att om undervisning och lärande inom *design och produktutveckling* på gymnasieskolan skall utvecklas behöver kunskapsområden från olika discipliner undersökas. I linje med detta resonemang har ingenjörer och industridesigners valts ut som informanter till denna studie.

¹⁸ Exempel på högskoleutbildning inom industridesign

<http://www.uid.umu.se/sv/utbildning/>

¹⁹ Exempel på ingenjörutbildning mot produktutveckling

<http://www.kth.se/utbildning/civilingenjor/design-produktframtagning/civilingenjor-design-och-produktframtagning-300-hp-1.4118>

²⁰ Exempel på lärarutbildning mot design

<http://www.konstfack.se/sv/Utbildning/Lararutbildning/>

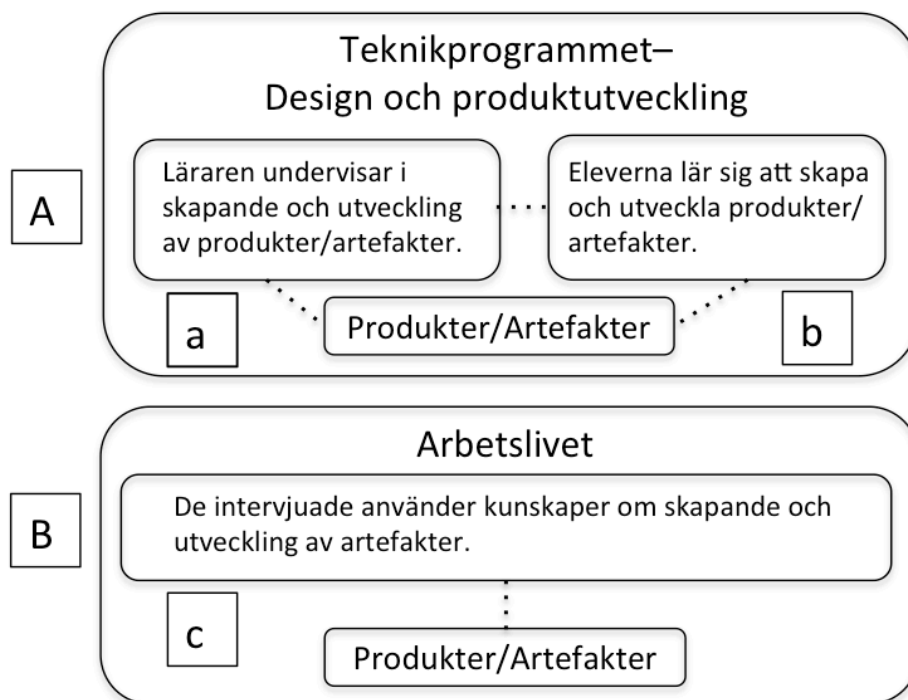
²¹ Exempel på lärarutbildning mot teknik

<http://www.kth.se/utbildning/civilingenjor/civing-larare/utbildningsbeskrivning-1.4108>

2 Forskningsfråga och syfte

Utbildningen inom inriktningen *design och produktutveckling* syftar till att ge eleverna användbar kunskap för vidare studier och arbete inom kunskapsområdet produktutveckling. I gymnasieskolan är de studieförberedande utbildningarna till mångt och mycket skilda från yrkeslivet. Detta visas i figur 2. Läraren undervisar eleverna i hur man skapar och utvecklar produkter (Figur 2Aa). Elevernas mål är att lära sig dessa förmågor (Figur 2Ab). Det finns en relation mellan lärare, elever och produkten/artefakten, detta samband demonstreras av de punktade linjerna i Figur 2A.

I arbetslivet skapar och utvecklar ingenjörer och industridesigners produkter/artefakter för en kommersiell marknad (Figur 2B). Även här finns en relation mellan de yrkesverksamma och produkten/artefakten (Figur 2Bc).



Figur 2 visar relationen mellan människor och artefakter och att skolverksamheten är separerad från yrkeslivet.

Elever som studerar produktutveckling ser sig ofta själva som blivande ingenjörer eller industridesigners. Skolans struktur främjar inte självklart en interdisciplinär hållning även om en sådan beskrivs som önskvärd i styrdokumentet (Skolverket, 2012). I denna studie vänder vi oss till ingenjörer och industridesigners som redan är verksamma inom produktutveckling för att få deras syn på kunskaper och färdigheter inom produktutveckling. Syftet är undersöka om det finns nyckelområden inom yrkeslivet som utbildning inom produktutveckling bör fokusera på och som främjar en interdisciplinär utbildning. Eftersom artefakter har en central roll inom produktutveckling undersöks även de intervjuades tankar och värdering av produkter/artefakter.

Baserat på detta resonemang ställs en övergripande delad forskningsfråga:

(a) Vilka tankar uttrycker yrkesverksamma ingenjörer och industridesigners beträffande nödvändiga kunskaper och förmågor och (b) vilken relevans kan detta ha för undervisning i produktutveckling inom gymnasieskolan?

För att undersöka detta har två delstudier genomförts och resultaten presenteras i två artiklar. I delstudie 1, som presenteras i artikel 1, undersöks vilka kunskaper ingenjörer och industridesigners anser vara viktiga inom sina respektive arbeten inom produktutveckling. Forskningsfrågan i delstudie 1 är:

- Vilka färdigheter och kunskaper inom produktutveckling anser yrkesverksamma industridesigners och ingenjörer vara betydelsefulla för sina respektive yrken?

Delstudie 2 som beskrivs i artikel 2 undersöker samma intervjupersoners tolkningar och värderingar av artefakter. Detta med syfte att undersöka intervjupersonernas uppfattningar om och relationer till artefakter. Forskningsfrågan i delstudie 2 är:

- Vilka egenskaper tillskriver ingenjörer och industridesigners åtta utvalda artefakter?

Delstudiernas resultat och deras relevans för utbildning kommer att diskuteras.

3 Bakgrund

Här presenteras en översikt av forskning och begrepp som influerat idéerna i detta arbete.

3.1 Teknikprogrammet, en översikt

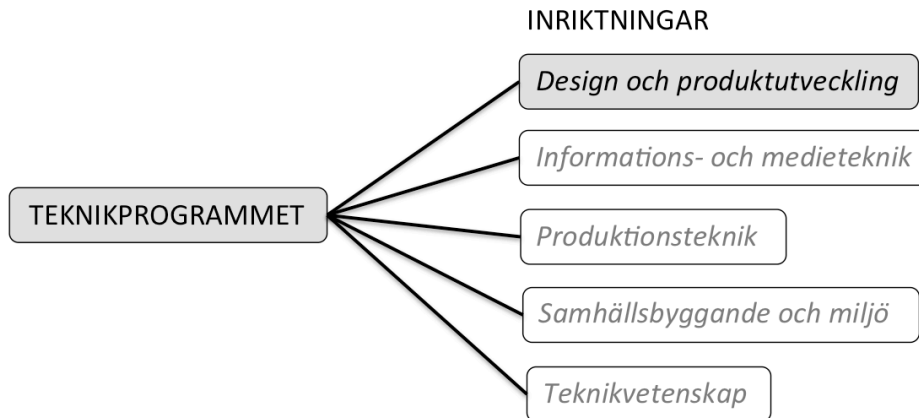
I Sverige idag har 91 % av befolkningen i åldersgruppen 25-34 år åtminstone gymnasial utbildning (OECD, 2013, tabell A1.2a).

Gymnasieskolan är en frivillig skolform och det finns 18 program att välja bland. 12 är yrkesförberedande och 6 är

högskoleförberedande (Skolverket, 2011). Olika styrdokument styr gymnasieskolan i Sverige, skollagen, gymnasieförordningen, läroplanen, examensmålen och ämnesplaner (Skolverket, 2011).

Dessa dokument hänger samman och är tänkta att skapa en meningsfull helhet (Skolverket, 2011).

Det utbildningssammanhang inom vilket forskningsintresset har väckts är Teknikprogrammet, ett av de högskoleförberedande programmen. Teknikprogrammet erbjuder fem inriktningar (Figur 2; Skolverket, 2011), en av dessa *Design och produktutveckling* skall utbilda inom kunskapsområdet produktutveckling. Detta kunskapsområde är centralt för denna avhandling. Som namnet indikerar är design och produkter viktigt för kunskapsområdet, i förlängningen kunskapen om artefakter. Detta diskuteras vidare i artikel 2.



Figur 3, Teknikprogrammets fem inriktningar. De fem inriktningarna täcker fem olika kunskapsfält.

Teknikprogrammets utveckling är av intresse då det visar på vilka teknikområden samhället ansett vara betydelsefulla. Högre teknikutbildning i Sverige har sitt ursprung inom militären (Sundin, 1991). Från tidigt 60-tal till 1994 var högskoleförberedande teknikutbildning på gymnasiet ett separat program inriktat mot vidare studier inom ingenjörsvetenskapen (Lindmark, 2009; Sweden, 1994; Göteborgs universitet, 2009). På grund av snabb teknisk utveckling och nya krav från arbetsmarknaden ansågs programmet otidsenligt. Att programmet inte heller lockade flickor bidrog till beslut att låta programmet bli en inriktning inom det naturvetenskapliga programmet (Sverige. Regeringen, 1988; Skolverket, 1992). Efter hand ställde intressenter från näringslivet och forskarsamhället krav på ett renodlat teknikprogram på gymnasienivå (Sverige. Regeringen, 1994) och 1998 fick Skolverket i uppdrag att utarbeta program mål och innehåll för ett nytt teknikprogram. Det nya programmet introducerades hösten 2000. Programmet innehöll nya tvärvetenskapliga ämnen och utformades som en både yrkes- och högskoleförberedande gymnasieutbildning. Utbildningen skulle kunna beskrivas som utgående från ett holistiskt förhållningssätt till teknik och teknikutveckling med särskilt fokus i människors förhållande till artefakter. Utbildningen var inte längre inriktad på specifika tekniska kunskaper eller yrken (Sweden, 1988; Skolverket,

1998). Detta gav skolorna stor frihet att lokalt utforma programmets karaktär.

Under 2011, genomgick gymnasieskolan en genomgripande reform (Sweden, 2008b). Teknikprogrammet ändrades igen, denna gång till att bli enbart högskoleförberedande med fem definierade inriktningar (Figur 2; Skolverket, 2012), anledningen till detta var att renodla programmets karaktär och attrahera fler till att söka högre tekniska studier (Sweden, 2008a; Skolverket, 2011a).

Teknikprogrammet har fortfarande svårigheter att attrahera kvinnliga sökande; läsåret 2012/13 utgjorde flickor endast 16 procent av de sökande (Skolverket, 2013c).

Inriktningen *Design och produktutveckling* är i antal elever näst störst av programmets inriktningar och ungefär 28 procent av eleverna i årskurs 2 är flickor (Skolverket, 2013c). Efter gymnasiet kan eleverna, om de vill fortsätta studera produktutveckling, söka ingenjörutbildningar²² eller utbildningar inom industri design²³. Andra alternativ är utbildning via yrkeshögskolan som erbjuder utbildningar inom områden som efterfrågas av näringslivet²⁴. Det finns också en möjlighet att inom gymnasieskolan ansöka om ett fjärde år som då leder till en gymnasieingenjörsexamen²⁵, även denna utbildning sker i samarbete med näringslivet.

3.2 Design

I dag erbjuder Teknikprogrammet fördefinierade inriktningar som täcker fem kunskapsfält (Figur 2). Dessa reflekterar dagens idéer om vad som anses som viktig teknisk kunskap och ger en ledtråd om

²² Exempel på ingenjörutbildning mot produktutveckling
<http://www.kth.se/utbildning/civilingenjor/design-produktframtagning/civilingenjor-design-och-produktframtagning-300-hp-1.4118>

²³ Exempel på högskoleutbildning inom industridesign
<http://www.uid.umu.se/sv/utbildning/>

²⁴ Exempel på utbildning inom yrkeshögskolan mot produktutveckling
<https://www.yrkeshogskolan.se/Utbildningar/Teknik-och-tillverkning/CAD-konstruktor---produktutvecklingdesign-2012202501/>

²⁵ <http://www.skolverket.se/fran-skola-till-arbetsliv/yrkesutbildningar/2.8114/ett-fjarde-ar-for-gymnasieingenjorsexamen-1.197488>

framtiden då detta kommer att påverka elevernas karriärer och liv. När det gäller eleverna från *Design och produktutveckling* kan vi se fram emot individer med kunskaper från både de naturvetenskapliga och konstnärliga disciplinerna. Förutom de gymnasiegemensamma ämnena finns de programgemensamma ämnena, fysik, kemi och teknik. Eleverna läser även ämnen specifika för inriktningen, för *Design och produktutveckling* är de Cad (Computer-aided design), Design, Bild och Konstruktion (Skolverket, 2011). Dessa ämnen är intressanta då de pekar på vad som anses vara specifikt för kunskapsområdet design och produktutveckling och att inriktningen är av tvärvetenskaplig karaktär.

Design är ett luddigt begrepp i det svenska språket och i de skandinaviska länderna traditionellt länkat till hantverk och konstnärskap (Sparke, 2009; Engineering and Product Design Education Conference, 2005). I Svenska Akademiens ordlista förklaras ordet med *konstnärlig formgivning*²⁶. På engelska förklaras ordet²⁷ med att planera i sinnet och fatta beslut kring något som ska skapas och att göra planerna och ritningarna för detta som visar hur det ska förverkligas. I denna bemärkelse fungerar ordet även på svenska inom ingenjörsvetenskap och i tekniska sammanhang. Att innebörden av ordet design har förändrats märks inom relativt nya ingenjörsutbildningar där ordet design signalerar att utbildningen har en inriktning där kreativitet och estetiska perspektiv är av vikt^{28 29 30}.

I gymnasieskolan introducerades design först som en kurs inom ämnet *Teknikutveckling* inom det teknikprogram som lanserades 2000 (Isaksson Persson, 2010). Från 2011 är *Design*³¹ ett eget ämne och obligatoriskt inom inriktningen *Design och produktutveckling*. Design

²⁶ http://www.svenskaakademien.se/svenska_sprak/svenska_akademiens_ordlista/saol_pa_natet/ordlista

²⁷ <http://www.merriam-webster.com/dictionary/design>

²⁸ <http://www.chalmers.se/sv/utbildning/program-pa-grundniva/Sidor/Designingenjor.aspx>

²⁹ <http://www.kth.se/utbildning/program/civilingenjor/design-produktframtagning/civilingenjor-design-och-produktframtagning-300-hp-1.4118>

³⁰ <http://www.ltu.se/edu/program/TCTDA>

³¹ <http://www.skolverket.se/laroplaner-amnen-och-kurser/gymnasieutbildning/gymnasieskola/sok-amnen-kurser-och-program/subject.htm?lang=sv&subjectCode=des&tos=gy>

kan även ingå inom andra program som programfördjupning. I grundskolan finns inte design som eget ämne men design är integrerat i och finns representerat i kursplanerna för bild och slöjd³².

Donald Schön beskriver arkitekt, produktdesigner och produktionsingenjör som klassiska designyrken, men han påpekar också att design är ett brett begrepp, inte enbart kopplat till dessa yrken (Schön, 1987, 2003). Pei (2009) menar att “the term ‘design’ is concerned with idea-based disciplines comprising of industrial design, engineering design, communication design, architecture, fashion and many others” (p.15). En industridesigner och designforskare i Sverige beskriver design som;

[...] design är ett begrepp som man kan använda på flera sätt. [...] en förmåga till handling och problemlösning kan man säga för att förbättra våra villkor. Men sen är design också [...] ett yrke. Då behöver man nästan sätta ett prefix på det om man pratar om grafiskdesign eller industridesign eller modedesign. Det är en professionell tillhörighet som har vissa specifika kunskaper om det området, om material, om tillverkningstekniker, om olika sociala koder och om kommersiella sammanhang och så. Men ska säga att gemensamt för de olika designprofessionerna är att handlar om att skapa någon typ av artefakter.

(Intervju av författaren, 2010-03-27).

Designtänkande är baserat både i huvudet och i händerna och kunskap om hur man både läser och gör skisser, ritningar och modeller är nödvändiga (Cross, 2000, 2007; Kroes, 2009; Ferguson, 1978; Kimbell & Stables 2007; Stiftelsen Svensk industridesign, 2007). Cross sammanfattar detta; “Everything around us that is not a simple untouched piece of Nature has been designed by someone” (2000, s.3).

I denna studie ses designverksamhet och designtänkande som verktyg för att omvandla idéer från abstraktioner till artefakter, kunskap som många olika yrken använder och har nytta av. Vi påstår inte att alla som deltar i produktutveckling eller i utbildning

³² <http://www.skolverket.se>

med fokus på produktutveckling är designers. Snarare att både ingenjörer och designers behöver kunskap som kan klassificeras som designkunskap. Oavsett om eleverna från *Design och produktutveckling* väljer en karriär som ingenjörer eller designers kommer de att bära med sig designkunskap.

De Vries (2005) menar att det finns experter som kan läsa artefakter, som känner igen och förstår den dolda kunskapen i dem. Vi anser att de intervjuade, i denna studie, har sådan kunskap och att den är nödvändig för dem i deras arbete.

3.3 Att analysera den visuella världen

När vi skapar och utvecklar en produkt, behöver vi förutom förmågan De Vries (2005) beskriver även förmågan att kunna visualisera en artefakt innan den existerar. Ferguson, (1978) kallar förmågan att visualisera en icke-existerande artefakter *visuellt* eller *icke-verbalt tänkande*.

Many objects of daily use have clearly been influenced by science, but their form and function, their dimensions and appearance, were determined by technologists-craftsmen, designers, inventors, and engineers-using non-scientific modes of thought. [...] The designer and the inventor, who bring elements together in new combinations, are each able to assemble and manipulate in their minds devices that as yet do not exist.

(Ferguson, 1978, s. 131)

Utifrån egen undervisningserfarenhet kan jag argumentera för att när man undervisar elever utan tidigare erfarenhet av att skapa artefakter, ger man dem verktyg att utveckla det visuella tänkandet. Eleverna behöver förmåga att analysera ett objekts karaktärer för att själv kunna skapa ett. Först har de en allmän uppfattning om artefakten, exempelvis en stol, men de måste förstå mer om konceptet stol. Ett sätt att göra detta är att undersöka stolen noga och förstå dess olika delar.

Arnheim (1997) diskuterar komplexiteten i vår användning av perception för att förstå världen och menar "Visual perception is

visual thinking” (s. 14). Utifrån våra visuella sinnesintryck generalisera vi och skapar en mental bild, vår egen förståelse för vad vi ser (Arnheim, 1997). Goldschmidt (2007) diskuterar hur vi visuellt läser vår omvärld och kallar detta *visual literacy*, en visuell läskunnighet. Goldschmidt hävdar att *visual literacy* är kontextberoende och kopplat till den kultur i vilken den är rotad (2007).

Begreppet *professional vision* kan få oss att förstå hur yrkesverksamma använder *visual literacy*. Goodwin (1994) undersöker aktiviteter i yrkeslivet och finner att seendet inte enbart är en perception utan även ett fenomen inom den sociala praktiken. Han menar att *professional vision* är “socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (Goodwin, 1994, p. 606). Han betonar även att olika yrkesgrupper tolkar samma fenomen på olika sätt (Goodwin, 1994). När man socialiseras in i en disciplin *professional vision*, är språket och det professionella ordförrådet viktigt.

Lymer (2009) undersöker arkitektutbildning och finner att kritik är ett sätt för lärare att utveckla studenternas *professional vision*. Lymer (2009) visar hur arkitekturlärare socialiserar eleverna in i yrket genom att uppmuntra dem att lära sig att *se som* arkitekt. Under utbildningen antas eleverna successivt utveckla ett ordförråd typiskt för arkitekter, detta gäller även presentationstekniker teckningsmanér och modellering. Studenterna lär sig både ett visuellt och ett retoriskt förhållningssätt och socialiseras gradvis in i yrket. Baserat på det tidigare resonemanget är det rimligt att hävda att ingenjörer och industridesigners inom produktutveckling behöver och använder förmågor för att läsa den visuella världen och att de besitter *professional vision*.

Ingenjörer och industridesigners inom produktutveckling utvecklar olika aspekter av artefakter och har traditionellt utbildningar från olika discipliner. Ledsoe (2005) beskriver hur teknikutveckling, historiskt sett, separerats från hantverk och

efterhand blivit mer relaterad till vetenskap. En artificiell gräns har skapats mellan teknik och design. Pei (2009) redogör för ingenjörers och industridesigners olika kunskapsområden inom produktutveckling. Han menar att ingenjörer och industridesigners är aktiva i designprocessen men har olika fokus på produkten. Industridesignern är engagerad i produktens form, användbarhet och identitet. Ingenjören är engagerad i att hitta och lösa tekniska problem genom att tillämpa vetenskaplig kunskap. Pei (2009) pekar på konflikter mellan ingenjörer och industridesigners. Även om de måste samarbeta och komplettera varandra har de olika ansvarsområden, språk, koder och regler, de har olika *object worlds*.

3.4 Komplexiteten i tvärvetenskaplig integration

Tidigare var produktutvecklingsprocessen linjär; den påbörjades med marknadsanalys, följd av forskning, produktdesign, konstruktion och slutade med tillverkning (Bohemia & Harman, 2008). Många organisationer har dock gått ifrån från denna process till produktutveckling i tvärfunktionella team där specialister från olika avdelningar samarbetar i parallella designprocesser (Bohemia & Harman, 2008).

Persson (2005) undersöker komplexiteten i tvärvetenskaplig integration inom produktutveckling. Ingenjörers och industridesigners arbetsprocesser är beroende av varandra, men betraktas inte som en gemensam process. De två disciplinernas ursprung i olika epistemologier hämmar kommunikation och interaktion.

På organisationsnivå försökte företagen hon undersökte att överbrygga klyftan mellan disciplinerna. Trots dessa ansträngningar försvårades samverkan mellan de två yrkesgrupperna på grund av deras olikheter.

3.5 Kunskap i yrkeslivet

Höghielm (1998, 2005) beskriver kunskap inom yrkeslivet och definierar begreppet *yrkeskunskap* utan att vinkla det mot ett speciellt

yrke. Vidare menar han att yrkeskunskap är kopplat till begreppen yrkeskultur, yrkespraxis och yrkeskompetens (Höghielm, 1998, 2005). Yrkeskulturen är baserad i ett yrkes traditioner och är normativ, den formar yrkespraxis och definierar även till viss del vad som räknas som yrkeskunskap. Yrkespraxis är de regler och procedurer som används inom ett visst yrke.

Förutom yrkeskunskap kan en kunskap av mer generell och tvärvetenskaplig natur bli identifierad i yrkeslivet. Definitioner och namn på denna förmåga skiljer sig från länder och sammanhang några exempel är 'key skills', 'key qualifications', 'key competences' och 'new basic skills' (Kämäräinen, 2002). I denna avhandling används termen *key qualification*. Key qualification associeras till en persons kapacitet att samarbeta, hantera nya situationer, ta initiativ, inneha social kompetens, vara flexibel, kommunikativ, analytisk och lösa problem samt till förmågor som är knutna till att kunna språk och hantera datorer (Höghielm, 2005; Höjlund, Göhl, & Hultqvist, 2005; Kämäräinen, 2002). Detta beskrivs vidare i delen *Theoretical framework* i artikel 1.

4 Metod

4.1 Den övergripande forskningsprocessen

Detta är en kvalitativ forskningsstudie (Alvesson & Sköldberg, 1994; Hartman, 2004; Marshall, & Rossman, 2006; Patel & Davidson, 2003; Williams & May, 1996) bestående av två delstudier, en genomförd som en semistrukturerad intervju och den andra med *repertory grid technique* (RGT). I den första studien undersöks tolv ingenjörer och industridesigners tankar om kunskap och kompetens i arbetet. Samma tolv intervjupersoners tolkningar och värdering av artefakter undersöks i den andra delstudien.

I den första delstudien användes ett frågeformulär (Bilaga 1) som intervjuguide och i den andra användes RGT. Alla intervjuerna spelades in utom en då den intervjuade inte ville det, i detta fall fördes anteckningar istället. Alla intervjuer utom en genomfördes på de intervjuades arbetsplatser.

4.1.1 De intervjuade

Tolv yrkesverksamma industridesigners och ingenjörer har intervjuats: fem kvinnliga och två manliga industridesigners samt tre kvinnliga och två manliga ingenjörer. Industridesignerna är den grupp som har mest homogen utbildningsbakgrund. Alla har en högskoleutbildning med examen inom design eller konst. Ingenjörerna har en mer divergerad utbildningsbakgrund, en har en doktorsexamen, en har en master, tre har gått fyraårig teknisk linje på gymnasiet med kompletterande utbildningar via arbetsplatsen.

4.2 Datainsamling

4.2.1 Datainsamling delstudie 1

Intervjuerna baseras på öppna frågor från ett frågeformulär (Bilaga 1) som har använts som en intervjuguide (Hartman, 2004; Patel & Davidson, 2003; Sweden, 2010). Frågeformuläret användes på så sätt att frågorna lästes upp av intervjuaren för intervjupersonen.

Frågorna 1 till 4 (Bilaga 1) ger information om intervjupersonernas utbildningsbakgrund. Frågorna 5 till 7 uppmärksammar intervjupersonernas skäl till varför de blev ingenjörer och industridesigners. Frågorna 8 till 13 fokuserar på intervjupersonernas tankar kring vilka färdigheter och kunskaper de anser vara viktiga inom yrket. Under intervjuerna flödade diskussionen fritt och frågorna besvarades inte alltid i ordning. Intervjuaren ställde följdfrågor för att förtydliga uttalanden eller för att föra tillbaka diskussionen till de fokuserade frågeområdena.

Inspelningarna transkriberades och kategoriserades (Holsti, 1976; Jankowicz, 2004). De intervjuades svar på frågeformulärets frågor 8, 9, 10, 12 och 13 (Bilaga 1) fanns vara av speciellt intresse och låg till grund för den vidare analysen.

4.2.2 Datainsamling delstudie 2

Syftet är att undersöka hur ingenjörer och industridesigners tolkar artefakter. RGT valdes eftersom denna teknik ger möjligheter att inkludera artefakter (Björklund 2008b; Jankowicz, 2004; Jordan, & Persson, 2007; Lindström 2001; Persson, Hiort af Ornäs & Jordan, 2007) och låta intervjupersonerna ta en aktiv roll i intervjusituationen.

Metoden härstammar från George Kellys arbeten och baseras på hans *theory of personal constructs* (Fransella, Bell & Bannister 2004; Jankowicz, 2004; Kelly, 1963). Även om metoden har en kvantitativ struktur är det främst en kvalitativ metod vars främsta syfte är att påvisa hur människor uppfattar sin omvärld (Jankowicz, 2004). Kelly menar att vi baserar vår syn på omvärlden utifrån våra tidigare erfarenheter. När vi genom våra erfarenheter tolkar världen använder vi flerdimensionella attribut som Kelly kallar *constructs* (Kelly, 1963). Dessa berättar dels vad vi tycker är typiskt för det som är i fokus för tolkningen men även vad som är motsatsen till detta. Detta gör att attributen (*constructs*) har två poler som kontrasterar varandra.

Åtta objekt har valts ut av intervjuaren, en cykelhjälm, en juldekoration, en vattenkanna, en håltagare, några bestick, en cigarrask, ett grenuttag och en figurin i form av en ren. Dessa visas för varje intervjuad, tre åt gången. Den intervjuade beskriver en egenskap som två av objekten har gemensamt men inte det tredje. Det tredje objektets egenskap blir motpol och kontrast till den egenskap de två andra objekten innehar. Dessa egenskaper bildar de två dimensionerna (polerna) hos ett *construct*. Intervjuerna har resulterat i sammanlagt 119 *constructs*. Genom ett beräknings- och värderingsförfarande som beskrivs ingående i artikel 2 kan de intervjuades *constructs* jämföras och analyseras.

4.3 Etiska överväganden

Riktlinjerna från Vetenskapsrådet (Gustafsson, Hermerén, & Petersson, 2005) har följts.

Yrkesverksamma ingenjörer och industridesigners är upptagna och det var svårt att hitta informanter till denna studie. De medverkande arbetar i två olika städer i Sverige, både kvinnor och män är representerade likaså olika åldrar och år i yrket. Dessa personer har blivit informerade om syftet med studien och accepterade att medverkade.

5 Resultat

5.1 Summering av resultaten i delstudie 1, artikel 1

Forskningsfrågan i delstudie 1 löd: *Vilka färdigheter och kunskaper inom produktutveckling anser yrkesverksamma industridesigners och ingenjörer vara betydelsefulla för sina respektive yrken?*

Enligt de intervjuade fick de redan i sin utbildning en första insikt i vad det innebär att vara ingenjör eller industridesigners. De fick då dessutom nödvändiga baskunskaper, i studien kallade *basic knowledge and skills*. I sitt yrkesliv fördjupade de intervjuade dessa kunskaper

och adderade nya, kallade *specific vocational knowledge and skills*. Dessa kunskaper är av vikt för att kunna genomföra de dagliga arbetsuppgifterna. Ingenjörer och industridesigners besitter olika sorters *specific vocational knowledge and skills* och utvecklar olika aspekter av produkter inom produktutvecklingsprocessen. Båda yrkesgrupperna har däremot kunskap om visualisering med hjälp av digitala modeller. Verket de intervjuade refererar till när de diskuterar utveckling av digitala modeller är CAD (Computer-aided design). Vilken mjukvara de arbetar med varierar men gemensamma egenskaper är ett gränssnitt med en tredimensionell rymd i vilken digitala objekt kan skapas. De intervjuades förmågor är inte begränsade till skicklighet i att använda en viss mjukvara utan de kan även tolka de digitala modellerna på dataskärmen och manipulera dem så att slutresultatet kan användas för att ta fram en slutprodukt som möter de ställda kvalitetskraven. De intervjuade använder ett verb för att beskriva denna färdighet, de "*caddar*" – i denna studie kallad, *to CAD*.

Både ingenjörer och industridesigners arbetar i team. De har sina givna uppgifter i teamet men för att nå det slutgiltiga målet för produktionsprocessen att producera en slutprodukt så är det inte tillräckligt att inneha specifika kunskaper och färdigheter eller att lösa speciella uppgifter. De intervjuade behöver även interagera med andra: de samarbetar, kompromissar, kommunicerar och leder. Dessa förmågor kan klassas som *key qualifications* (Kämäräinen, 2002). Resultaten i denna studie utvidgar Höghielms (1998, 2005) definitioner av yrkeskunskaper och beskriver hur specifika yrkeskunskaper och *key qualifications* är sammanflätade. Förmågor av denna art kallas i denna avhandling *to act within the team*. Denna förmåga är nödvändig för de intervjuade för att navigera och positionera sig inom teamet. Både ingenjörer och industridesigners saknar träning i detta från sina utbildningar.

5.2 Summering av resultaten i delstudie 2, artikel 2

Forskningsfrågan i delstudie 2 löd: *Vilka egenskaper tillskriver ingenjörer och industridesigners åtta utvalda artefakter?* Resultaten visar hur de intervjuade applicerar vissa tydliga karaktärsdrag på fyra av artefakterna, en juldekoration, en håltagare, ett grenuttag och en renfigurin. I denna studie menar vi att de intervjuade diskuterar dessa artefaktens funktionalitet, deras *functional nature* (De Vries, 2005). Renfigurinen och juldekorationen anses vara utan funktion och associerade till ord som; icke nytta, utseende, personlig tillfredställelse, socialt beteende, mjuk, sentimentala värderingar och hemmiljö samt till ord som estetik/dekoration. Dessa attribut sammanfattas och ges ett namn, den dekorativa funktionen, *decorative function*. Håltagaren och grenuttaget associeras däremot enbart med funktion. De beskrivs som, användbara verktyg och förknippas med teknik, smarthet och skydd. Med avstamp i Kelly (1963) kan de fyra artefaktens *constructs* ses som kulturella uttryck som beskriver artefaktens funktionella egenskaper. Om vi dessutom ser på detta kulturella uttryck genom att använda *dualistic gender metaphors* (Wajcman, 2004) ser vi att den dekorativa funktionen tillhör en annan sfär än funktionen hos håltagaren och grenuttaget. Styrdokumenten för teknikprogrammet tar upp sambandet mellan genus och teknik (Skolverket, 2012, 2013b).

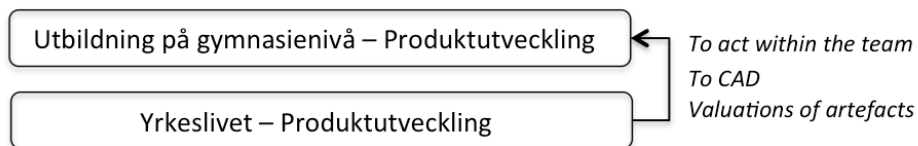
Baserat på resultaten från denna studie önskas en vidare diskussion och forskning kring våra relationer och värderingar till och om artefakter och hur dessa påverkar undervisning och lärande. Speciellt inom undervisning i teknik och design, där artefakter har en central plats, borde våra kulturella värderingar av artefakter vara en del av klassrumsdiskussionen.

6 Diskussion

Här diskuteras resultaten från varje delstudie och reflekteras i styrdokumenterna för gymnasieskolan inklusive examensmålen för teknikprogrammet. Den övergripande forskningsfrågan beaktas igen:

(a) Vilka tankar uttrycker yrkesverksamma ingenjörer och industridesigners beträffande nödvändiga kunskaper och förmågor och (b) vilken relevans kan detta ha för undervisning i produktutveckling inom gymnasieskolan?

Efter analys träder tre olika teman fram som passar att fokusera på inom gymnasieskolans teknikprogram mot design och produktutveckling. Dessa områden rör kunskaper av generell och tvärvetenskapliga natur, i studien kallad *To act within the team*, visualiseringsförmåga kallad *To CAD* och värderingar av artefaktens funktionalitet kallad *Valuations of artefacts* (Figur 4). De första två är relaterade till forskningsfrågan i delstudie 1 och den tredje till forskningsfrågan i delstudie 2.



Figur 4 visar de teman som beskriver viktiga kunskaper och förmågor inom produktutveckling som kan användas inom gymnasieutbildning.

6.1 To act within the team

I den första delstudien (Artikel 1) utforskas frågan om vilka färdigheter och kunskaper inom produktutveckling som yrkesverksamma industridesigners och ingenjörer anser vara betydelsefulla för sina respektive yrken?

Resultaten visar att de intervjuade uppskattar de baskunskaper som de fick inom sina respektive utbildningar samt den första inblicken i yrkets karaktär. De intervjuade betonade även vikten av yrkets specifika kunskaper. För ingenjörer exempelvis, matematik,

problemlösning och frågor rörande konstruktion. Industridesignerna betonade förmågor att skissa och modellera som viktiga kompetenser. Förutom detta betonades kunskap av mer generell karaktär så som att samarbeta, kompromissa, kommunicera med mera. I denna studie kallas denna förmåga *to act within the team*. Denna kunskap är sammanflätad med de specifika kunskaper som är nödvändiga för att lösa de dagliga arbetsuppgifterna. Styrdokumenten för den svenska gymnasieskolan är vaga kring hur eleverna ska utveckla denna typ av generell kunskap. "Eleverna ska i skolan få utveckla sin förmåga att ta initiativ och ansvar och att arbeta både självständigt och tillsammans med andra." (Skolverket, 2011b, s. 7) eller " Utvecklingen i yrkeslivet innebär bland annat att det behövs gränsöverskridanden mellan olika yrkesområden och att krav ställs på medvetenhet om såväl egen som andras kompetens." (Skolverket, 2011b, s. 7). Skolverket refererar till EU's rekommendationer om nyckelkompetenser (Skolverket, 2011a, s. 13; European Union, 2007). De fortsätter "I gymnasieskola 2011 ska gymnasiegemensamma ämnen samspela med programmets karaktärsämnen, och det är genom fördjupning i den programspecifika karaktären som eleven utvecklas också som medborgare och som individ." (Skolverket, 2011a, s. 13). Examensmålen för teknikprogrammet är mer specifika; "[...] utbildningen ska ge eleverna kunskaper om och färdigheter i att samarbeta med andra" och utbildningen ska "[...] ge kunskaper om projektarbete och färdigheter i att arbeta i projekt [...]" (Skolverket, 2011a, s. 269).

De intervjuade saknar träning i teamwork från sina utbildningar och har olika åsikter kring hur de lärt sig detta. Vissa betonar sociala aktiviteter och samarbete med andra utanför den reguljära undervisningen, andra refererar till erfarenheter från projektarbeten med kolleger och kunder i yrkeslivet. Styrdokumenten för gymnasieskolan förespråkar utveckling av denna typ av kunskaper men forskning saknas kring hur skolan i praktiken påverkar detta (Skolverket, 2013a).

Teknikprogrammet kan vara en arena för att studera detta just för att styrdokumentet betonar kunskaper och förmågor i samarbete och projektarbete (Skolverket, 2012). Frågor att ställa kan röra lärarnas inställning till samarbete, kommunikation och ledarskap. Vilka metoder och strategier används? Vad tror eleverna att de lär sig när de samarbetar inom projekt? RGT kan användas för att undersöka både lärare och elevers idéer vad samarbete och projektarbete är.

6.2 To CAD

Resultaten i artikel 1 visar att CAD är ett viktigt verktyg för visualisering. De intervjuade uppskattar denna kunskap och beskriver den med ett verb, de caddar, i denna studie kallat *to CAD*. Industridesigner O5 beskriver det på följande sätt.

O5: Jag visualiserar. [...] först tänkte jag säga att jag caddar och skissar, men det är liksom bara verktyg för att få fram den...

Intervjuare: Så det ingår i visualisera?

O5: Det ingår i visualisering, [...] CAD och skiss och modell [...].

Intervju med industridesigner O5, 2009-03-23, s.5

Denna kunskap innefattar inte enbart skicklighet i att använda en viss mjukvara utan inkluderar även förmåga att utveckla en digital modell som representerar och slutprodukten och håller de uppsatta kvalitetskraven.

De intervjuade har olika uppfattningar om hur man blir skicklig i att cadda. En industridesigner tror att unga människor som enbart arbetar i CAD och saknar erfarenhet av att själv bygga och reparera saker saknar viktig förståelse. En ingenjör tror att det är en lägningsfråga.

Intervjuare: Och CAD har du lärt dig på jobbet?

O1: På jobbet, ja. Det var väldigt roligt, det kände jag. Olika människor har, en del har CAD-gener och andra har det inte och jag har en CAD-gen.

Intervju med ingenjör O1, 2009-01-10, s.3

Vid visualisering med CAD verktyget behövs förståelse för relationen mellan modellen på skärmen och den icke existerande slutprodukten. Ett exempel på detta är följande citat från ingenjör O1 som diskuterar hur den digitala modellen på skärmen kommer att skilja sig från slutresultatet.

Precis för det, det måste man förstå. [...] säger man att någonting ska vara 11,3 mm så blir det inte 11,3 mm utan det blir 11,3 mm plus, minus någonting. I CAD blir det 11,3, 000000000 men i verkligheten så blir det inte så [...]. Så bara för att det blir helt perfekt i CAD så blir det inte det på riktigt sen.

Intervju med ingenjör O1, 2009-01-10, s.7

Examensmålen för teknikprogrammet diskutera inte vad som karakteriserar visualisering. Inom inriktningen *design och produktutveckling* finns ämnena CAD (Computer-aided design), bild, konstruktion och design, ämnen specifika för inriktningen. I examensmålen står det, “ I inriktningen ingår ämnena cad, bild, konstruktion och design, vilket ger inriktningen en tydligt teknisk profil. Ämnet bild ger grunderna i färg och form medan ämnet cad ger det tekniska verktyget i designprocessen.” (Skolverket, 2011a, s. 277). Vi kan gissa att innehållet i dessa ämnen kan utveckla förmågan att visualisera. Så som industridesigner O5 beskriver visualisering, det är när hon både använder CAD och skissar som hon visualiserar.

Knorr Cetina och Bruegger (2002) undersöker börsmäklares relationer till dataskärmar. Dataskärmen visualiserar finansmarknaden och kopplar ihop mäklaren med denna. Börsmäklaren får via skärmen tillgång till kunskaper om priser, affärersuppgörelser etcetera, de blir på så vis en del av marknaden genom dataskärmen. Finansmarknaden på skärmen är en sammansättning av kunskap, ett *epistemic object*, inte begränsat till en viss grupp människor eller till specifika artefakter. Nerland (2008) beskriver ett *epistemic object* som ett verktyg som kan användas men samtidigt är under ständig utveckling. Om CAD-modeller betraktas som *epistemic objects*, är det möjligt att lära sig mer om förmågan att cadda?

6.3 Valuations of artefacts

Den andra delstudien genomförs med *repertory grid technique* (RGT) (Artikel 2) och undersöker följande forskningsfråga. *Vilka egenskaper tillskriver ingenjörer och industridesigners åtta utvalda artefakter?*

Resultaten visar att bland de artefakter som använts i intervjusituationen finns fyra som de intervjuade värderar på liknande sätt. Artefakterna med en tydlig dekorativ funktion (renfigurinen och juldekorationen) anses inte vara till nytta eller inneha någon funktionalitet. Industridesigner O11 sammanfattar dessa karaktärsdrag när renfigurinen beskrivs "*Den har ju ingen funktion, den har bara en estetisk funktion [...]*", i denna studie kallas denna egenskap den dekorativa funktionen, *the decorative function*. Den dekorativa funktionen associeras med utseende, estetik och personligt uttryck. I kontrast till den dekorativa funktionen beskrivs funktionerna hos håltagaren och grenuttaget som komplicerade, användbara, tekniska, smarta och associeras till skydd.

De intervjuades associationer har likheter med *the dualistic gender metaphors* (Wajcman, 2004), estetiska egenskaper sammankopplas med en annan sfär än funktionalitet och användbarhet. Enligt Kelly (1963) hör vi samman med kulturella grupper som tolkar världen på liknande sätt som vi gör. Baserat på detta resonemang kan de intervjuades tolkningar av artefakterna ses som kulturella uttryck. Styrdokumenten problematiserar till viss del förhållandet mellan teknik och genus "Teknik i sig är genusneutralt, men användningen av teknik är inte alltid det." (Skolverket, 2011a, s. 249). Önskvärt vore att styrdokumenten ytterligare diskuterade vårt förhållande till artefakter och teknik. Då skulle ett incitament finnas till diskussioner i klassrummet kring hur artefakter påverkar samhället och våra liv.

7 Fortsatt forskning

Denna studie visar att yrkesverksammas idéer om kunskaper och färdigheter inom produktutveckling kan visa på områden av betydelse för skola och utbildning. I studien har tre

faktorer/förmågor av särskild betydelse för framgång inom produktutveckling identifieras. De intervjuade, oavsett yrkestillhörighet, värderar artefaktens funktionalitet på ett likartat sätt. Vi vet inte om dessa värderingar är specifika för ingenjörer och industridesigners, vi vet dock att de inte förhåller sig neutrala till artefakterna. Upprepar sig dessa mönster inom utbildning mot design och produktutveckling? Detta kan undersökas med Repertory grid technique på ett liknande sätt som ingenjörers och industridesigners värderingar undersöktes i denna studie. Ingenjörerna och industridesignerna lyfter även fram förmågan att arbeta i team och att behärska visualisering med verktyget CAD. Även för vidare forskning kring skolans arbete inom dessa områden kan Repertory grid technique användas. Frågor som rör både undervisning och lärande kan undersökas. Vilka attityder till teamwork och visualisering har lärare och vilka strategier används för undervisning inom dessa områden. Utifrån ett elevperspektiv, vad tror eleverna att de lär sig när de deltar i aktiviteter som ska främja lärande inom teamwork och visualisering. På detta sätt kan resultaten från denna studie bli en grund till vidare forskning kring hur utbildning främjar kunskapsområden typiska för produktutveckling.

PART IV APPENDICES

Appendix 1. The interview guide used in sub-study 1.

Questionnaire questions

1. Name	Man	Woman
2. What is your profession?		
3. For how long have you worked in the profession?		
Number of years		
4. Education and training	Degree	Year
4a. Educational programme		
4b. Educational programme		
4c. Educational programme		
5. Do you think you have the right education for your profession? Explain your answer.		
6. Why did you choose your profession?		
7. Are you satisfied with your career choice? Explain your answer.		
8. Give three examples of knowledge or skills that you learned during your education that you consider are of special importance for you in your profession. Explain why these skills or knowledge have been of particular importance.		
8. Example 1		
Explain your answer		
8. Example 2		
Explain your answer		
8. Example 3		
Explain your answer		
9. Are there any skills or knowledge that you did not learn during your education that would have been useful in your professional practice?		
10. Can you give examples of skills or knowledge that you learned in your professional practice that you have not learned during your education?		

11. How did you learn this?
12. Give three examples of tasks that you perform frequently in your work.
12. Example 1
12. Example 2
12. Example 3
13. Rank the three most important items of knowledge or skills for practitioners of your profession.
13. 1
13. 2
13. 3

Appendix 2. 50 pairs of constructs analysed in sub-study 2.

RF = Reindeer figurine, CTO = Christmas tree, MS = Multiple socket, RPP = Revolving punch pliers (4) = includes all four elements. (3) = includes three of the elements. Italics = includes decoration/aesthetics and/or function				
	Elements	Constructs: left pole	Constructs: right pole	Elements
1, Engineer O1				
1:1 (4)	RF, O(1) E(2) = 3 CTO, O(2) E(2) = 4	One material. Easy to use. (87.5%)	Several materials. Complicated. (87.5%)	MS, S(M) C(M) = 4 RPP, S(M) C(M) = 4
2, Engineer O2				
2:2 (4)	RF, D(2) A(2) = 4 CTO, D(2) A(2) = 4	Decoration. Appearance. (87.5%)	Function/ usefulness. Protect. (87.5%)	MS, F(2) P(2) = 4 RPP, F(2) P(1) = 3
2:3 (3)	CTO, S(2) E(2) = 4	Soft Easy to produce (81.2%)	Hard Difficult to produce (81.2%)	MS, H(1) D(1) = 2 RPP, H(2) D(1) = 3
3, Industrial Designer O3				
3:4 (4)	RF, F(2) F(1) = 3 CTO, F(2) F(2) = 4	Feminine. Playful, decorative. Fragile. (87.5%)	Masculine materials, including function. Stable. (87.5%)	MS, M(2) S(2) = 4 RPP, M(2) S(2) = 4
3:5 (3)	RF, I(2) O(2) = 4	Industrial design, designer. Ornate. (84.4%)	Engineering design, production method determines. Stripped. (84.4%)	MS, E(1) S(2) = 3 RPP, E(2) S(2) = 4
3:6 (3)	RF, P(2) O(2) = 4	Playfulness. Ornate. (84.4%)	Functional design. Stripped. (84.4%)	MS, F(2) S(2) = 4 RPP, F(2) S(2) = 4
3:7 (4)	RF, P(2) F(1) = 3 CTO, P(1) O(2) = 3	Playfulness. Fragile. (84.4%)	<i>Functional design. Stable.</i> (84.4%)	MS, F(M) S(M) = 4 RPP, F(M) S(M) = 4
3:8 (4)	RF, D(2) F(2) = 4 CTO, D(2) F(2) = 4	Decorative. Feminine. Playful, decorative (84.4%)	Technological. Masculine materials, including function.	MS, T(M) M(M) = 4 RPP, T(M) M(M) = 4

			(84.4%)	
3:9 (3)	RF, M(2) D(2) = 4 CTO, M(2) D(2) = 4	Mechanical. <i>Decorative.</i> (84.4%)	A shell with something electric. Smartness. Technological. (84.4%)	MS, A(2) T(2) = 4
3:10 (4)	RF, P(2) I(2) = 4 CTO, P(1) I(2) = 3	Playfulness . Industrial design, designer. (81.2%)	<i>Functional design.</i> Engineering design, production method determines. (81.2%)	MS, F(2) E(1) = 3 RPP, F(2) E(2) = 4
3:11 (4)	RF, D(2) P(2) = 4 CTO, D(2) P(1) = 3	<i>Decorative.</i> Playfulness. (81.2%)	Technological. <i>Functional design.</i> (81.2%)	MS, T(2) F(2) = 4 RPP, T(2) F(2) = 4
4, Industrial Designer O4				
4:12 (4)	RF, D(2) D(2) = 4 CTO, D(2) D(2) = 4	Decoration, to hang and look at. Décor. (96.9%)	They can be used, there are end users. Function-related product. (96.9%)	MS, T(2) F(2) = 4 RPP, T(2) F(2) = 4
4:13 (4)	RF, T(2) D(2) = 4 CTO, T(2) D(2) = 4	The main function is the appearance. <i>Decoration, to hang and look at.</i> (93.8%)	The main function is that it functions. They can be used, there are end users. (93.8%)	MS, T(1) T(2) = 3 RPP, T(2) T(2) = 4
4:14 (4)	RF, T(2) D(2) = 4 CTO, T(2) D(2) = 4	The main function is the appearance. Décor. (90.6%)	The main function is that it functions. Function-related product. (90.6%)	MS, T(1) F(1) = 2 RPP, T(2) F(2) = 4
4:15 (4)	RF, T(2) F(2) = 4 CTO, T(2) F(2) = 4	The main function is the appearance. Fulfils its purpose even with low functionality. (84.4%)	The main function is that it functions. Requires high functionality to be appreciated as a product. (84.4%)	MS, T(1) R(1) = 2 RPP, T(2) R(1) = 3
4:16 (4)	RF, D(2) F(2) = 4 CTO, D(2) F(2) = 4	Decoration, to hang and look at. Fulfils its purpose even with low functionality. (84.4%)	They can be used, there are end users. Requires high functionality to be appreciated as a product.	MS, T(2) R(1) = 2 RPP, T(2) R(1) = 3

			(84.4%)	
4:17 (4)	RF, F(2) D(2) = 4 CTO, F(2) D(2) = 4	<i>Fulfils its purpose even with low functionality. Décor.</i> (81.2%)	<i>Requires high functionality to be appreciated as a product. Function-related product.</i> (81.2%)	MS, R(1) F(2) = 3 RPP, R(1) F(2) = 3
5, Industrial Designer O5				
5:18 (4)	RF, S(1) P(2) = 3 CTO, S(M) P(1) = 3	Soft values. Should be in home environment. Placed so it will be exposed, will be noticed. (81.2%)	Technical, very mechanical, tool. Stored somewhere until it will be used. (81.2%)	MS, T(1) S(1) = 2 RPP, T(2) S(2) = 4
5:19 (3)	RF, W(2) P(2) = 4	Whole, to function independently. Placed so it will be exposed, will be noticed. (81.2%)	Designed to function together with someone or something. Stored somewhere until it will be used. (81.2%)	MS, D(2) P(1) = 3 RPP, D(2) S(2) = 4
6, Industrial Designer O6				
6:20 (4)	RF, S(2) P(2) = 4 CTO, S(1) P(1) = 2	Social behaviour. Pleasure purchase. (93.8%)	Functional behaviour. Need-based purchase. (93.8%)	MS, F(2) N(2) = 4 RPP, F(2) N(2) = 4
6:21 (4)	RF, A(2) S(2) = 4 CTO, A(2) S(1) = 3	Aesthetics. Social behaviour. (87.5%)	Function. <i>Functional behaviour.</i> (87.5%)	MS, F(2) F(2) = 4 RPP, F(2) F(2) = 4
6:22 (4)	RF, A(2) P(2) = 4 CTO, A(2) P(1) = 3	Aesthetics. Pleasure purchase. (87.5%)	Function. Need-based purchase. (87.5%)	MS, F(2) N(2) = 4 RPP, F(2) N(2) = 4
6:23 (3)	RF, N(2) I(1) = 3 CTO, N(2) I(1) = 3	Non-active use. Interest in how things look. (81.2%)	Active use. Interest in how things function. (81.2%)	RPP, A(2) I(2) = 4
7, Industrial designer O7				
7:24 (4)	RF, D(2) P(2) = 4 CTO, D(2) P(1) = 3	Decorates the home. Personal satisfaction/ expression. (93.8%)	Personal function. Function. (93.8%)	MS, P(2) F(2) = 4 RPP, P(2) F(2) = 4
7:25 (3)	RF, U(2) D(1) = 3	Unstable. Divided. (87.5%)	Stable. Unified. (87.5%)	MS, S(1) U(1) = 2 RPP, S(2) U(2) =

				4
7:26 (4)	RF, P(2) D(2) = 4 CTO, P(1) D(2) = 3	Personal satisfaction/ expression. Decoration. (84.4%)	<i>Function.</i> Tool. (84.4%)	MS, F(2) T(2) = 4 RPP, F(2) T(2) = 4
7:27 (4)	RF, D(2) D(2) = 4 CTO, D(2) D(2) = 4	<i>Decorates the home.</i> Decoration. (84.4%)	<i>Personal function.</i> Tool. (84.4%)	MS, P(2) T(2) = 4 RPP, P(2) T(2) = 4
8, Engineer O8				
8:28 (3)	RF, O(2) O(1) = 3 CTO, O(2) O(2) = 4	Ornaments. Old-fashioned. (90.6%)	Functional that you rather not see. New. (90.6%)	MS, F(1) N(1) = 2
8:29 (3)	RF, O(2) D(2) = 4 CTO, O(2) D(1) = 3	Ornaments. Decoration stuff. (87.5%)	<i>Functional that you'd rather not see.</i> Necessary but not sufficiently stylish. (87.5%)	MS, F(1) N(1) = 2
8:30 (3)	RF, C(1) R(1) = 2 CTO, C(1) R(1) = 2	Christmas ornament. Rarely used. (84.4%)	Everyday stuff. Often used. (84.4%)	MS, E(2) O(M) = 4
8:31 (3)	RF, D(2) U(2) = 4	<i>Decoration stuff.</i> Unnecessary stuff/ Does not exist in Swedish homes. (84.4%)	Necessary but not sufficiently stylish. Exist in Swedish homes. (84.4%)	MS, N(1) E(2) = 3 RPP, N(1) E(1) = 2
8:32 (4)	RF, D(2) O(2) = 4 CTO, D(1) O(2) = 3	<i>Decoration stuff.</i> On view/To be seen. (81.2%)	Necessary but not sufficiently stylish. Picked away. (81.2%)	MS, N(1) P(1) = 2 RPP, N(1) P(2) = 3
8:33 (3)	RF, O(2) O(2) = 4 CTO, O(2) O(2) = 4	Ornaments. On view/To be seen (81.2%)	<i>Functional, that you'd rather not see.</i> Packed away. (81.2%)	MS, F(1) P(1) = 2
9, Engineer O9				
9:34 (4)	RF, O(2) A(2) = 4 CTO, O(2) A(2) = 4	Ornaments. Aesthetics. (96.9%)	Useful. Function. (96.9%)	MS, U(2) F(2) = 4 RPP, U(2) F(2) = 4
9:35 (4)	RF, A(2) I(2) = 4 CTO, A(2) I(2) = 4	Aesthetics. Interior, want it displayed. (84.4%)	<i>Function.</i> Garage, not for display, want to hide away. (84.4%)	MS, F(2) G(2) = 4 RPP, F(2) G(2) = 4
9:36	RF, O(2) I(2) =	Ornaments.	Useful.	RPP, U(2) G(2) =

(4)	4 CTO, O(2) I(2) = 4	Interior, want it displayed. (81.2%)	Garage, not for display, want to hide away. (81.2%)	4 MS, U(2) G(2) = 4
10, Industrial Designer O10				
10:37 (3)	RF, N(2) S(2) = 4 CTO, NI(1) S(1) = 2	Not useful. Short life. (90.6%)	Useful. Long life. (90.6%)	RPP, U(2) L(2) = 4
10:38 (4)	RF, D(2) N(2) = 4 CTO, D(2) N(1) = 3	Decorations. Not useful. (87.5%)	Tool. Useful. (87.5%)	MS, T(2) U(1) = 3 RPP, T(2) U(2) = 4
10:39 (4)	RF, O(2) A(2) = 4 CTO, P(NM) E(M) = 3	Ornaments. Aesthetics. (87.5%)	Function. Ergonomics. (87.5%)	MS, F(2) E(1) = 3 RPP, F(2) E(2) = 4
10:40 (4)	RF, O(2) N(2) = 4 CTO, O(1) N(1) = 2	<i>Ornaments.</i> Not useful. (84.4%)	<i>Function.</i> Useful. (84.4%)	MS, F(2) U(1) = 3 RPP, F(2) U(2) = 4
10:41 (4)	RF, O(2) D(2) = 4 CTO, O(1) D(2) = 3	<i>Ornaments.</i> <i>Decorations.</i> (84.4%)	<i>Function.</i> Tool (84.4%)	MS, F(2) T(2) = 4 RPP, F(2) T(2) = 4
10:42 (3)	RF, O(2) S(2) = 4 CTO, O(1) S(1) = 2	<i>Ornaments.</i> Short life. (81.2%)	<i>Function.</i> Long life. (81.2%)	RPP, F(2) L(2) = 4
10:43 (4)	RF, A(2) D(2) = 4 CTO, A(2) D(2) = 4	<i>Aesthetics.</i> <i>Decorations.</i> (81.2%)	Ergonomics. Tool. (81.2%)	MS, E(1) T(2) = 3 RPP, E(2) T(2) = 4
10:44 (4)	RF, A(2) N(2) = 4 CTO, A(2) N(1) = 3	<i>Aesthetics.</i> Not useful. (81.2%)	Ergonomics. Useful. (81.2%)	MS, E(1) U(1) = 2 RPP, E(2) U(2) = 4
11, Industrial Designer O11				
11:45 (4)	RF, T(2) E(2) = 4 CTO, T(1) E(2) = 3	The shape guides the design. Entertaining. (93.8%)	The function guides the design. Suited to its purpose. (93.8%)	MS, T(2) S(2) = 4 RPP, T(2) S(2) = 4
11:46 (4)	RF, A(2) E(2) = 4 CTO, A(2) E(2) = 4	An elaborated shape. Entertaining. (90.6%)	The shape a result of the construction. Suited to its purpose. (90.6%)	MS, T(1) S(2) = 3 RPP, T(2) S(2) = 4
11:47 (4)	RF, E(2) N(1) = 3	Entertaining. Nostalgic,	Suited to its purpose.	MS, S(2) N(2) = 4

	CTO, E(2) N(2) = 4	sentimental value. (84.4%)	No feelings for the product. (84.4%)	RPP, S(2) N(2) = 4
11:48 (4)	RF, A(2) N(1) = 3 CTO, A(2) N(2) = 4	An elaborate shape. Nostalgic, sentimental value. (81.2%)	The shape a result of the construction. No feelings for the product. (81.2%)	MS, T(1) N(2) = 3 RPP, T(2)N(2) = 4
12, Engineer O12				
12:49 (4)	RF, S(2) N(2) = 4 CTO, S(1) N(1) = 2	Sentimental value. No function. (87.5%)	Tool. Function. (87.5%)	MS, T(2) F(2) = 4 RPP, T(1) F(1) = 2
12:50 (3)	RF, F(1) S(2) = 3 CTO, F(1) S(1) = 2	Festival. Sentimental value. (81.2%)	Everyday. Tool. (81.2%)	RPP, E(2) T(2) = 4

ⁱ All eighteen (18) national programmes give general qualifications for higher vocational education.

ⁱⁱ This type of hierarchy, in which interdependence and communication create boundaries between different occupational groups, has been described before by Bechky (2003). She examines in an ethnographic study the dynamic of boundaries between three different occupational groups; engineers, technicians and assemblers at a manufacturing firm. Engineers create representations of a new product in the form of drawings, technicians use the drawings to make a prototype and assemblers use the prototype to understand how the product should be assembled. The engineers that have carried out the mental creation of the product own the artefact and are highest

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Theses in Education and Communication in the Technological Sciences from the Royal Institute of Technology (KTH)

1. Eva Hartell, *The Inefficient Loneliness. A Descriptive Study about the Complexity of Assessment for Learning in Primary Technology Education*, Licentiate thesis, 2012.
2. Lennart Rolandsson, *Changing Computer Programming Education; The Dinosaur that Survived in School: An explorative study of educational issues based on teachers' beliefs and curriculum development in secondary school*. Licentiate thesis, 2012.
3. Gunilla Rooke, *In Search for Gender awareness in Technology Education*. Licentiate thesis, 2013.
4. Helena Isaksson Persson, *Bridging the boundaries between D&T education and working life. A study of views on knowledge and skills in product development*. Licentiate thesis, 2015.