Timeless, socially relevant engineering knowledge and skills for future technology education

Per Norström, KTH Royal Institute of Technology
perno@kth.se
Susanne Engström, KTH Royal Institute of Technology
sengstro@kth.se
Birgit Fahrman, KTH Royal Institute of Technology
birgitf@kth.se

ABSTRACT

The aim of technology education in primary and secondary school is that students should acquire skills and knowledge that are useful not only today, but also when they are adults. Students' knowledge and skills need to include aspects of engineering and crafts as well as social implications of technology, which together develops creativity, useful everyday skills, critical thinking, and more. This leads to special challenges for technology teacher education, which has to look forward and focus on future challenges. The training needs to include timeless skills and be both about and for the technological future. Exactly which knowledge and skills that are best suited for this endeavour is not in any way clear. The purpose of this paper is to find the timeless and socially relevant engineering methods and skills that could and should be taught in primary and secondary school to increase the likelihood that students are properly prepared for the future. The project has an exploratory approach. Data were collected through focus group interviews with different participant groups: technology teachers in lower and upper secondary school, teacher students aiming to become technology teachers, and teachers working in academic teacher training programmes. The results show that the question about timeless knowledge has rarely been discussed in these groups. They had no clear answers, but ended up mainly in traditional technology education content: writing technical reports, learning strategies for design and product development, and fundamentals of computer programming. The results suggest that the respondents believed strongly in pupils' ability to transfer skills and knowledge between domains.

Key Words: technology education, engineering education, timeless knowledge, future education

1. INTRODUCTION

Modern technology education in primary and secondary school took off in the 1980s and 1990s, and spread across the world. The subjects vary considerably between countries, but generally emphasize crafts, engineering science, and societal aspects of technology (Nordlöf et al., 2022).

Compared with older school subjects such as physics and mathematics, there is little consensus concerning its contents. Focus varies between countries, with well-known examples such as Scotland and Finland emphasizing crafts, Massachusetts emphasizing computers and modern engineering, while Sweden's and New Zealand's curricula stress the history and sociology of technology (Norström, 2022). All technology subjects share several challenges. One that has received a lot of interest from the education research community is the (sometimes) complicated relationship between technology and the natural sciences in educational contexts. Another well-researched area is the role of design work in technology education. Other problems, that have not received the same amount of attention, include the question of timelessness and durability of technological knowledge.

In Sweden, what pupils learn about technology in school at the age of 13 should be useful in their everyday lives, but also aid them in choosing a suitable branch of secondary education at the age of 16, and to understand political, ethical, and practical technological problems throughout their adult lives. For this to be possible, what they learn has to have some degree of timelessness. Predicting the technological future – and the knowledge necessary to understand it and act in it – has proven difficult for engineers as well as for historians and sociologists of technology (cmp. Bowler, 2017). In the early 2000s, many experts claimed that ethanol was soon to replace fossil fuels. Ten years later, other experts ascertained that autonomous vehicles would fill roads and streets within just a few years. Technology textbook authors also make erroneous predictions of the future. In commonly used Swedish upper secondary school textbooks (Frid, 2011; Nyberg, 2011), obsolete 3D manufacturing methods are described along the soon-to-come technological revolutions enabled by the mass-production of graphene. Attempts to include future technologies and methods in the teaching risk making it seem abstract and irrelevant, as it is difficult to relate to today's world. If the predictions turn out to be incorrect, they risk becoming ridiculous. ITEA addresses the problem of prediction in their *Standards for technological literacy* (2007, p. 1):

> Because technology is so fluid, teachers of technology tend to spend less time on specific details and more on concepts and principles. The goal is to produce students with a more conceptual understanding of technology and its place in society, who can thus grasp and evaluate new bits of technology that they might never have seen before.

Exactly which knowledge, skills, 'concepts and principles' that are best suited for this endeavour is not in any way clear, and the standards are not helpful with concrete advice for how to make the aspirational learning take place. Instead, it has to be developed mainly in the community of technology teachers, teacher educators, and curriculum designers.

The purpose of this paper is to find the timeless and socially relevant engineering methods and skills that according to teachers and teacher educators could and should be taught in primary and secondary school to increase the likelihood of pupils' being well prepared for the future. The study is planned as the first step in a larger project about timeless technological knowledge. It has an exploratory approach and uses focus group interviews. The number of respondents is low, but they represent different groups within the technology education community. Thereby, they approach the opportunities and difficulties concerning timeless, socially relevant engineering knowledge and skills for future education in different ways.

The study should answer the following questions:

- What characterises timeless and society-relevant knowledge in the technology subject according to technology teachers, technology teacher students, and technology teacher educators in Sweden?
- How do they work to implement this?

The study is mainly descriptive. The results will be useful as inspiration for teachers, teacher educators, curriculum designers and for future research in technology education.

2. TECHNOLOGY EDUCATION IN SWEDISH SECONDARY SCHOOLS

In Sweden, technology is a mandatory subject for all pupils throughout the nine years of compulsory schooling. The contents have a wide scope. For the youngest pupils, focus is on everyday technologies. In lower secondary school (years 7–9; pupils are 13–16 years old) pupils study the design process, infrastructure, modern materials, automatic control using programmable systems, the relationships between technology, the arts, and the natural sciences, and more (Skolverket, 2022).

In upper secondary school, technology is a subject for students who have chosen the technology programme (c. 8–10 % of the student population, with considerable geographic variation). While technology education in compulsory school is for everyone, the explicit purpose of upper secondary school technology is to prepare for future studies and work in the domains of technology and engineering (Skolverket, n.d.).

3. DATA COLLECTION

Data were collected through focus group interviews with selected groups from the educational community. Using focus group interviews enable the respondents to discuss and develop their responses together. Through their conversation, they express their understanding and through the jointly conducted dialogue, the responses are developed further. The interviewers can ask questions to encourage clarification, and nudge the respondents if the conversation comes to a halt. Having a safe environment for the interview is important (Marshall & Rosman, 2011). The focus-group interviews in this study were carried out mainly at the respondents' workplaces. The respondents are well acquainted with each other – they are colleagues at a school, students in the same education programme, or teacher educators who meet regularly.

3.1. Respondents and interview procedure

The respondents consisted of four groups, gathered through convenience sampling:

- *Lower secondary school technology teachers*. Three experienced teachers, working in a municipality-owned school in an upper middle class area.

- *Upper secondary school technology teachers*. Three experienced teachers, working in a municipality-owned school, specialised in computer science and invention.
- *Technology teacher students*. Nine former engineers, participating in a bridging teacher education programme at a Swedish university with the aim of becoming secondary school teachers.
- *Technology teacher educators*. Five teacher educators (lecturers, senior lecturers) representing 4 different higher education institutions.

The keywords ‘timeless, socially relevant engineering knowledge and skills for future education’ were written on a whiteboard (in Swedish). These words served as a starting point for the discussion, and both interviewers and interviewees returned to them during the conversation. Each group-interview lasted between 30 and 60 minutes. The interviews were recorded (audio only), and transcribed verbatim. Data collection took place during the autumn of 2022, and the spring of 2023.

3.2. Data analysis procedure

The interview transcripts were analysed using thematic analysis, inspired by Braun and Clarke (2006). The three authors read the transcripts repeatedly. Recurring themes were identified. Thereafter, notes and themes were compared, and similar themes combined. This enabled both the content of what the respondents brought up to be framed, and also emphasized the interactive qualities of the conversations.

4. RESULTS AND ANALYSIS

When comparing the themes from the different groups of respondents, both similarities and differences came up. This concerns both what kinds of themes that were discussed, and how they were addressed. The secondary school teachers highlighted examples from their own teaching practices. They returned to what pupils would find interesting or difficult several times. They also made more frequent references to the curriculum documents than the other groups. The upper secondary school teachers stressed the need to be skilled in maths for a future career in technology, which the lower secondary school teachers did not. The teacher educators focussed on the challenges of teachers and teacher students. They talked about how teachers should stand up and be proud of their subjects, and the need for courage and self-confidence for the ability to teach. The participating teacher students, of whom many had recently worked in engineering, often referred to their own experiences as pupils and students. Just like the upper secondary school teachers, they mentioned maths as essential for a career in technology or engineering, but also self-confidence, initiative, and an attitude of curiosity.

The respondents were not used to discuss the abstract concept of timeless knowledge, or even knowledge that would stay useful over time. In many cases, the discussion drifted towards engineering skills. Social, historical, and ethical knowledge stayed in the background for most of the time.

Below, the themes that emerged from the entire material, across all participant groups, are presented. Thereby, we aim to highlight what characterises timeless and socially relevant engineering skills and knowledge, suitable to address in technology education in secondary school, as interpreted by respondents involved in technology education in various roles. The themes below are not discrete, but overlapping.

4.1. Timeless knowledge areas within the Swedish technology subjects

The respondents highlighted certain technological areas where it was especially important that pupils should develop knowledge and skills. These were referred to as 'timeless' or 'likely to be useful in the future', but also as 'necessary for all engineers', and referred to as 'indispensable parts of technological literacy'. The most commonly mentioned areas were computers and programming; electronics; energy; and mechanics. The lower secondary school teachers mentioned houses and the built environment in general. The upper secondary school teachers mentioned the history of technology. Surprisingly enough, none of the groups talked at length about infrastructure or large technological systems.

A rudimentary knowledge of computers and computer programming (by some respondents referred to as 'computational thinking' or 'general digital competence') was emphasised by all groups. Fundamental programming skills and concepts such as variables, conditional statements, and loops were considered important to understand, and believed to withstand the test of time. The secondary school teachers mentioned common electronic components, their names, and use. Especially the upper secondary school teachers stressed the need to understand how components are combined with computers and processors to perform automatic control tasks.

Both teachers and teacher educators mentioned classical mechanical technological solutions such as levers, inclined planes, and screws. One of the teachers reminded their group that they are truly timeless: 'They have been at the core of technology education since antiquity, and will be used forever.'

Energy, especially the production of electricity, was also mentioned numerous times. The discussion never really took off however. The reason for this could be that energy, energy distribution, and energy politics, traditionally belong to the subjects of physics and civics in Swedish curricula.

Other knowledge areas mentioned in passing include knowledge of the history of technology, ethical aspects related to technology, knowledge of various standards, materials, and durability.

4.2. Timeless methods, procedures, and skills

It was obvious that the respondents found it easier to discuss timeless methods, procedures and skills, compared with propositional knowledge. Several times, strong beliefs in the possibility of transferring a method or skill-set from one domain to another were expressed. This concerned areas such as the writing of technical reports ('They look more or less the same, no matter what kind of technology they deal with') to a general engineering design process, applicable for many kinds of technical problem solving or product development tasks.

Teaching of a structured design process has been the core of technology education in many countries for a long time (probably most notable in the United Kingdom). The Swedish technology curricula have always described a broader subject, in which design and product development is just one theme among others (history of technology, large technical systems, the relations between science and technology, etc.; Skolverket, 2022). Nevertheless, even in Sweden the learning of a design process is considered essential and timeless technology education content. The upper secondary school teachers mentioned how design and product development work encourage curiosity and provides a framework for learning about technology in general. The lower secondary school teachers also mentioned this, for example in relation to learning about how to write technical reports and how to use flowcharts and technical drawings. The teacher students talked about the importance of learning how to collaborate, and how design and development work could provide an environment for this.

The upper secondary school teachers, who were keen on programming, mentioned software engineering as an important form of design or product development work. They described the skills and the attention to detail needed for systematic testing, analysis, and debugging of software as to some degree transferrable to other technical domains. Furthermore, the upper secondary school teachers meant that product development work encouraged information retrieval and critical thinking. If the project is large enough, and authentic enough, pupils will repeatedly run into problems that neither they nor their teachers know how to solve: 'Google, and see what you can find. There is a lot of rubbish out there, but also useful stuff. You learn how to find it by trying.' Environmental awareness, life cycle analysis, risk assessment, and mathematical and physical modelling are also considered timeless skills that can be practiced in a design process environment.

4.3. Attitudes

Despite our question focusing on knowledge and skills, the need to develop sound attitudes towards technology and engineering was brought up numerous times. The respondents described how a timeless, socially relevant, engineering-focussed attitude must be positive towards and comfortable with technology; it is characterised by a desire to investigate, discover, and solve problems, as well as to understand one's choices and being able to create technology oneself. The individual and their opportunities that each person can gain through an innovative attitude are in focus.

Skills such as analysing environmental impact or ethical implications of technologies was mainly discussed through attitudes. The respondents discussed the need for pupils to develop an environmental awareness, and recognize their own (and the Western world's) roles in the technosphere. They did however not discuss how this could be done, or how these attitudes could encourage scientific evaluation of the impact of lifestyle choices or new innovations. The suggestions never went beyond developing an awareness of possible problems, and an attitude implicating that a solution can be found.

An attitude towards technology that will withstand the test of time is also described as action-oriented, curious, and insightful about how the world works. Throughout the education, students should be encouraged to develop a personal desire to learn and a willingness to face technical problems that they cannot yet understand (preferably socially relevant ones). According to the respondents, an innovative, self-directed, and playful attitude is important for students' will and abilities to approach timeless, socially relevant, and engineering aspects with their 'problem-solving mental toolkits.'

5. DISCUSSION

During the last decades, the most important way of educating technology teachers in Sweden has been through re-training of engineers. The group of respondents reflects this. Almost all of them have some kind of background in engineering: the upper secondary school teachers were all former engineers who had re-trained to become teachers, the teacher students were former engineers, as were a majority of the teacher educators. This has most likely affected the results, as most discussions started out with an engineers' view of technology, rather than that of an artisan, an economist, a historian, a politician, or an average citizen.

The task set in front of the respondent groups proved to be a difficult one. Trying to frame parts of the Swedish technology subjects is always difficult, as the contents cover wide areas of knowledge, the content has changed considerably with every new version of the national curriculum, and the subject's informal canon of content and exercises is weak. It does not get any easier if the task is not to describe just what content that would be useful today, but also what would be useful in the future. Many predictions about the technological future have proven wrong, and it is of course difficult for technology teachers to determine what the technological future will look like. What constitutes the 'more conceptual understanding of technology [that enables pupils to] grasp and evaluate new bits of technology that they might never have seen before' (as ITEA, 2007, p. 1, put it)? That gears, inclined planes and screws belongs there seems likely. But what more? Technical reports will most certainly be written in the future, but will they be written by humans? Autocad and Microsoft Word have been around since the early 1980s, will they still be widely used ten years from now? The respondents in this study, i.e. groups of technology teachers, technology teacher students, and technology teacher educators stressed that knowledge about mechanics, electronics, and elementary computer programming was timeless. This content already have prominent positions in the Swedish curricula. The respondents did not talk about specific tools, but general concepts. 'Timelessness' was however not elaborated upon beyond the almost trivial 'useful in the future'. The respondents could provide examples of knowledge that they considered timeless, but obviously found it more difficult to motivate their choices or suggest an overarching description of what united them.

This is a work in progress. In a near future we will deepen our understanding of what the educational community thinks about timeless, socially relevant knowledge and skills in technology. The next step will be to interview stakeholders such as industrial companies and institutions of higher technical education. The results will be useful for curriculum design and educational development, and could provide input to a general discussion about the purpose of technology education in school.

When both society and technology changes rapidly, teachers and teacher educators will have to make several difficult choices. Should we teach about technologies for a world with higher temperatures, lack of drinking water, microplastics in the oceans, less political stability, and no fossil fuels? Or should we teach about technologies for a world where everyone is a happy vegetarian, surviving on organic food from the local co-op, travelling only on bicycles built from recycled cardboard? Something in between? That is a choice for politicians and curriculum developers. Hopefully, this study can inspire to further studies within the area.

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