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Technology teachers' talk about knowledge: from uncertainty to technology education competence

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ABSTRACT

Background: The subject of technology looks different depending on context. There is also an epistemological complexity to technological knowledge in technology education.

Purpose: To gain a deeper understanding of the epistemological foundations of the subject of technology and technology teaching, the teachers' views are needed. The aim of this study is to examine how teachers discuss technology education, with a particular focus on how they talk about technological knowledge.

Sample: 19 Technology teachers from compulsory school in Sweden participated.

Design and methods: Through focus groups, teachers' views of knowledge in technology education were collected and then analysed.

Results: The results consist of three parts. Firstly, it was found that the teachers were unfamiliar with discussing epistemology in technology education. Secondly, interpreting their views of knowledge in technology education through a theoretical framework for knowledge in technology education yielded examples of knowledge from the three constituent categories: technical skills, technological scientific knowledge, and socio-ethical technical understanding. Finally, an inductive analysis revealed two categories based on the teachers' broader views of knowledge: civic capabilities and engineering capabilities.

Conclusion: Overall, the results provide an understanding of teachers' ways of describing technological knowledge. The teachers perceived the term knowledge in a broader way than traditional epistemology, including capabilities in their descriptions. We propose a new perspective on the character of knowledge and capability in technology education, called technology education competence. The results of this study point to important aspects of the nature of the subject, which might lead to reflection about what knowledge should be considered of value in the future regarding research but especially development of curricula.

KEYWORDS

Technology education; technological knowledge; epistemology; technology teachers

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Introduction

Technology education is a school subject that includes a variety of knowledge content depending on the type of school, the syllabus, and the national education system, which might lead to difficulties in understanding, discussing, and comparing technology education in different contexts (Jones, Buntting and de Vries 2013). In technology education, the issue of what the central knowledge components of the subject actually constitute is therefore an underdeveloped area, not only due to the epistemological complexity of technological knowledge and the wide range of technology curricula in different national contexts (Doyle, Seery, and Gumaelius 2019; Stoor and Popov 2021), but also because teachers are not used to discussing the subject in terms of knowledge components (cf. Hultén 2019). Some prior studies have addressed epistemological issues in relation to technology teachers' narratives of subject content; for example, Doyle, Seery, Canty et al. (2019), who characterise teachers' views of technological practice. Norström (2014) concludes that technology teachers' views of knowledge vary substantially, and that philosophical discussions on knowledge in particular are unknown to them.

Scientific exploration of teachers' conceptions of and talk about technological knowledge could expand the research-based, epistemological foundation of technology education since teachers are the primary actors in curriculum delivery and their experiences are based on real educational practices (cf. Biesta, Priestley, and Robinson 2017). Nordlöf et al. (2021) proposed a framework for technology education, intended to facilitate comparison, discussion, and development of the epistemological foundation of the subject in relation to different contexts, an *epistemological tripod of technology education* where each leg is based on a tradition of knowledge: (1) technical skills, (2) technological scientific knowledge, and (3) socio-ethical technical understanding. This framework is a conceptual model intended as a support for teachers' planning and conducting of technology teaching, thereby anchoring the epistemology of the subject in real classroom practice. If teachers are able to distinguish technological knowledge from other kinds of knowledge, for example, it can deepen their knowledge and, as a consequence, improve technology teaching (de Vries 2016).

The aim of this study is to examine how teachers discuss technology education, with a particular focus on how they talk about technological knowledge. This is done to gain a deeper understanding of the epistemological foundations of the subject of technology and technology teaching, from the teachers' point of view. The main research question is: How do teachers discuss technological knowledge in technology education?

Background and previous research

Technological knowledge

A common definition of knowledge is that it is *justified true belief* (e.g. de Vries 2005; Turri 2012). However, this formulation is not very useful when considering technological knowledge, which includes a normative component (de Vries 2016). Philosophers have proposed different definitions of what technological knowledge is and what engineers know (e.g. Mitcham 1994; Ropohl 1997; Vincenti 1990). To grasp what technological knowledge might be requires us to understand the aim of technology, which, in turn, indicates that technological knowledge must be described differently than other fields of

knowledge (e.g. science). In this regard, de Vries (2016) describes the respective goals of science and technology as follows: 'science aims at developing new knowledge about reality as it is, while technology aims at changing reality according to our needs and desires' (p. 31). Consequently, technology has to do with the *designed* or *human-built world*. That is, it consists of the knowledge required to design, construct and use technological artefacts and systems in order to solve societal problems in a broad sense (e.g. Ropohl 1997; Mitcham 1994; Hughes 2004). In this study, technological knowledge is more closely defined in relation to the epistemological tripod of technology education (Nordlöf et al. 2021). In addition, technological capability is used to denote the ability to perform something, mentally or physically, by integrating a range of different types of knowledge. Doyle, Seery, Canty et al. (2019) write that 'to be considered technologically capable it is necessary to apply both knowledge and skills in solving practical problems while acknowledging and engaging with value-laden decisions' (p. 145). Capability is a wider construct than knowledge; hence, capability can also include aspects such as attitude or personal characteristics.

Technological literacy

The concept of technological literacy constantly recurs in technology education literature and curricula, often forming part of the aim of technology education (e.g. in Sweden, Skolverket 2017). The American *Standards for technological and engineering literacy* describes technological literacy as 'the ability to understand, create and assess the human-designed environment that is the product of technology and engineering activity' (International Technology and Engineering Educators Association 2020, 8).

The concept of technological literacy focuses on an overall understanding of technology, which implies abandoning a focus on technology as consisting mainly of artefacts and appliances (e.g. Dakers 2006). According to Williams (2017), technology education has historically been characterised by a narrow view of technology, whereas today it is a context for developing technological literacy, which he views as one of the main goals of technology education. Rossouw, Hacker, and de Vries (2011) also argue that gaining technological literacy is the main aim of technology education, and describe it as 'what people need to live in, and control, the technological environment that surrounds us. This literacy comprises practical knowledge, reasoning skills, and attitudes' (Rossouw, Hacker, and de Vries (2011), 411).

Although there is no single consensus definition, the above examples demonstrate that the concept of technological literacy is often connected to a multidimensional, holistic view of technology, which also includes a broader array of technological knowledge components that are needed in order to participate in an increasingly technology-dependent society (Williams 2017).

Teachers' conceptions of knowledge content in technology education

Doyle, Seery, Canty et al. (2019) investigated Irish technology teachers' descriptions of their practice by interviewing 15 experienced teachers. Three themes were identified: the prominence of activities focused on the development of technical

competencies, the pressures involved in meeting the requirements of summative assessment, and teachers' professional views on capability in the discipline. The authors conclude that the enacted practice of the teachers does not always match what they find to be important in technology education.

Wu and Ding (2020) studied secondary school technology teachers' conceptions of technology teaching (COTT), which involves teachers' descriptions of such teaching. The studied teachers find technology teaching to be either teacher centred or student centred with respect to the three aspects of *Knowledge, Technology skills* and *Technology literacies*. These teachers generally considered knowledge of technology to consist of learning about technology to facilitate students' future lives and learning, of which technological literacy is one part.

Fahrman et al. (2020) explored the considerations of experienced technology teachers in lower secondary school. One finding concerning technological knowledge is that teachers in this study prioritised design and making activities in technology education before ensuring that other subject content was covered. The authors conclude that, in practice, the respondents 'define this subject mainly by project work in which the pupils are to develop the abilities' (Fahrman et al. 2020, 183). Yet another finding is that problem solving and developing problem-solving skills among students are central aspects of technology education, as well as the design process.

Fahrman studied conceptualisations of the subject of technology in her licentiate thesis (Fahrman 2021), by focusing on novice technology teachers participating in a professional development course. The study focuses on the purpose of technology education and what teachers believe is most important to learn. Hence, even though studying knowledge in technology education is not the main purpose, the results are partly related to knowledge, in the form of content. Four themes were found concerning the content of technology education: Technology in society, Technical solutions, the Design process, and Engineering thinking. The participating teachers also talked about a special understanding of the subject, which is often referred to as 'engineering thinking' (Fahrman 2021, 46), described as 'a competence or understanding of the technology subject' (p. 46), specific to technology education. However, this understanding is not clearly defined in her study.

Method

Context

In this study, teachers representing all nine years of compulsory school participated. The teachers thus have different experiences, backgrounds, educations, and knowledge of technology.

Swedish compulsory school consists of three educational levels: grades 1–3 and grades 4–6 (primary education), and grades 7–9 (lower secondary education). Technology is a mandatory subject throughout the whole of compulsory school.

Teachers in grades 1–3 are usually 'class teachers' who teach most subjects. The organisation in grades 4–6 takes different forms in different schools, with some organised around class teachers, while others employ subject teachers. In grades 7–9 the teachers are all subject teachers, often teaching between two and four subjects.

To be qualified as a teacher of technology requires a teacher education. To become a qualified subject teacher in grades 7–9 it is also possible to be given credit for previous education, for example engineering studies, and complement that with a basic teacher education. Qualified teachers can apply for certification in their subjects after one year in service, and it is also possible to be certified as a technology teacher without proper technology credits after eight years in service.

Research design

In response to the research question, a qualitative approach was taken where focus groups were employed as research methodology. Focus groups enable researchers to 'study and understand a particular topic from the perspective of the group participants themselves' (Wibeck, Dahlgren, and Öberg 2007, 250), and is thus suitable for investigating how teachers as a collective discuss the specific subject of knowledge in technology education. The methodology of focus groups gives an opportunity to gain a deeper understanding of the thoughts and experiences of the participants by encouraging dialogue and discussions among them (Morgan 1996). The participants thus discuss a topic and an interviewer encourages interaction to generate data (e.g. Wibeck, Dahlgren, and Öberg 2007). The goal is to let all participants reveal their views rather than reaching a consensus in the group (Allen 2017). The group itself can push the conversation forward based on their interest (Morgan 1996). The first author took the role as a moderator and aimed to find a balance between being active and passive, and focused more on listening than speaking, thereby facilitating the discussions by for example encouraging some participants to take part in the conversations, and keeping focus on the subject (Allen 2017).

Participants

When using focus groups in research it is recommended to create small homogeneous groups (Wibeck, Dahlgren, and Öberg 2007; Allen 2017). The focus groups were each conducted with teachers from the same educational level. Since they were conducted digitally, teachers from all over Sweden were able to participate. Social media was used as the main recruitment route. Participants were found by presenting the project to interested teachers in teacher groups on Facebook. In addition, a couple of interested participants were found through personal networks. In total, 19 teachers agreed to participate and filled in a short questionnaire involving some background questions. All of them attended the focus groups, but one of the teachers had technical problems with the microphone throughout interview 4, and therefore only participated as a listener during parts of interview 4 and did not participate in the conversations at all. An overview of the participating teachers and their backgrounds is presented in Table 1. There were both women and men, and their ages varied between 33 and 63. All but one had a teacher education and certification to teach technology. Their experience as teachers varied from one to 33 years. Eight of the participants had other technical backgrounds (e.g. engineering education) apart from teacher education. Everyone taught one or more other subjects as well as technology.

Table 1. Overview of the participants.

ID	Focus group	Years since teaching degree	Teaching students in grades	Technology was studied during teacher education	Certification to teach technology	Other technical/ STEM background	Teaching subjects, apart from technology
Alexander	1	9	7–9	No	Yes	Yes	Ma
Agnes	1	33	7–9	No	Yes	Yes	Sc
Anthony	1	Teacher education, but not completed.	7–9	Yes	No	Yes	Cr
Bella	2	4	4–6	Yes	Yes	No	Sc, Ma, En
Bianca	2	8	4–6	Yes	Yes	No	Sc, Ma
Barbara	2	12	4–6	No	Yes	No	So, Sc, Sw, Ma
Celine	3	14	7–9	No	Yes	Yes	Sc, Ma
Charlie	3	5	7–9	No	Yes	Yes	Sc, Ma
Claudia	3	2	7–9	No	Yes	Yes	Ph
Charlotte	3	1	7–9	No	Yes	Yes	Ph, Ma
Daniella	4	18	1–3, 4–6	Yes	Yes	No	Sc, Ma, Sw
Doris	4	25	1–3, 4–6	Yes	Yes	No	Sc, Sw, So
Denise	4	14	1–3, 4–6	No, but was supplemented later	Yes	Yes	Cr, Art, Sc
Elizabeth	5	12	1–3	No	Yes	No	Sc, Sw
Emily	5	22	1–3, 4–6	No, but was supplemented later	Yes	No	Sc, Ma
Erin	5	11	1–3, 4–6	No	No	No	Ma, Sc, Sw, So
Frida	6	14	1–3	No	Yes	No	All subjects in grades 1–3
Felicia	6	17	1–3	Yes	Yes	No	(No answer)
Flora	6	14	1–3, 4–6	Yes	Yes	No	Sc

Note. Ma – mathematics, Sc – science subjects, Cr – craft, En – English, So – social science subjects, Sw – Swedish, Ph – physics.

Data collection

In all, six focus groups were conducted, two from each educational level. The interview guide was designed by creating different types of questions with different functions, in order to create a flow and a progression (Krueger 1998). All the focus groups were based on the same interview guide, but since they were conducted as conversations with a lot of room for interaction between the participants, each of them took a different shape and varied in length. All the focus groups started with a short round of presentations and background, and then each participant answered an opening question: *How would you describe technology education to someone who is not very familiar with it, for example, a parent?* The teachers were also asked to describe their teaching. Two recurring key questions were: *What kind of technological knowledge do you want your students to learn?* And *What knowledge is the focus in technology, compared to the other subjects you teach?* At the end of each focus group, the teachers had the opportunity to add something more, which in some cases led to several more minutes of discussion. The sessions were conducted between May and September 2020, and they were all recorded and transcribed in Swedish.

The research was conducted in accordance with ethical principles of the Swedish Research Council (Swedish Research Council 2017). All participants gave consent to recording after being informed about the study and their rights as research participants,

and that their personal data would be treated properly. During the actual data collection, the moderator worked according to recommendation from Wibeck, Dahlgren, and Öberg (2007), to 'help create an atmosphere of trust, in which participants believe that their contributions are important, and that there are no "rights" and "wrongs" to be assessed by the researchers' (p. 263).

Data analysis

The analytical approach was hermeneutic and thematic analysis was used (Braun and Clarke 2006). Since the data was rather extensive, the analysis was performed in several cycles, iterating between a focus on details and a holistic view. The analysis included both a deductive part, using an epistemological framework for technology education (Nordlöf et al. 2021), and an inductive part, where an open approach to the material was used to capture the teachers' views.

The epistemological tripod of technology education (Nordlöf et al. 2021) is a specific framework that has been developed in relation to knowledge in technology education with the intention of fitting most technology curricula. This framework builds on three categories of knowledge, based on professional and academic technological knowledge traditions (see Table 2 for further explanation). The framework was created with the intention of its being used in several ways. In this study, it is used to analyse the teachers' descriptions of technological knowledge.

Although the analysis process was ongoing over a long period of time, it can be described in a simplified way as consisting of six phases (Braun and Clarke 2006), performed in several iterations. These consisted of: (1) listening to the recordings, transcribing, and reading the transcripts to become acquainted with the material, followed by (2) a first impression coding. From these codes, (3) themes were identified and (4) further reworked and refined. Steps 2–4 were repeated several times, both inductively and deductively and by mixing procedures (by using the software MAXQDA, by reading and by writing). For example, when a teacher explained that she teaches about 'movement and construction and connects them to natural science' (Daniella), we used the above theoretical framework and interpreted this as technological scientific knowledge. An example from the inductive analysis is when Frida described her teaching: '[W]orking together has a lot to do with programming, and usually when you're a programmer you don't sit alone and solve tasks, you do it together'. We interpreted this excerpt as describing a wider view of knowledge in terms of what she wants her students to learn, which we interpreted as a capability, in this example the capability of working together to prepare the students for a future working life. Finally, (5) the themes were given descriptive labels and (6) examples of excerpts were chosen to illustrate the themes.

The results provide a picture of how these 18 teachers as a collective talked about technological knowledge in technology education. Thus, their individual views have not been the primary focus.

Table 2. The three-part heuristic framework for technology education.

	The three legs of the epistemological tripod of technology education		
	Technical skills	**Technological scientific knowledge**	**Socio-ethical technical understanding**
Brief description of technological knowledge (tradition)	The first technological knowledge mastered by humans. Skill or ability. The main focus is to make things work, not why they work. Knowledge in technology. (Craftmanship tradition)	Knowledge gained using a general scientific approach, but in a technological context. Understanding why things work is of the greatest importance. Knowledge in technology. (Engineering tradition)	Discussing and relating technology to different aspects such as the environment, society, and humans. Knowledge about technology and its relationship with the human world. (Humanities and social sciences tradition)
Main justification method	Experience	Methods from the technological and natural sciences.	Methods from the humanities and social sciences.
Example from technology education	Knowledge of how to build, cut, and glue cardboard models.	Knowledge of how materials are structured and their properties.	Knowledge of how computers have changed the way we communicate or how society's infrastructure is designed.
Example from professional activities	Craftwork of a blacksmith.	Mechanical calculations of the strength of a bridge.	How a new railway line will affect the everyday life of the local community.

Results

In the following, the results of the analyses are reported in three parts. The first part is based on the teachers' immediate answers about knowledge in technology, where our analysis was inductive. Parts two and three are based on two different forms of analysis. Part two was deductive and based on the epistemological framework for technology education presented above, while part three was based on an inductive thematic analysis.

Teachers' (in)experience of discussing knowledge

When analysing the focus group interviews, it became obvious that the participating teachers had not given technological knowledge very much thought before and that they were not used to talking about it. Nevertheless, they had a lot of teaching experience and ideas about teaching and students' learning in technology. When the teachers were asked about their teaching (e.g. *what technological knowledge do you focus on in your teaching?*), some of them answered that they did not understand the question or that it was a difficult question to answer.

When Charlie got a question about what technological knowledge is and what he wants his students to gain from technology teaching, he answered: (1) 'I'm not sure if I understand what you mean specifically by technological knowledge, really . . . ' He did not seem to have thought about technological knowledge in that way before. In the following exchange, Bella responded to a similar question and said that it was difficult to answer:

(2) Interviewer: Bella, what would you say is, kind of, in focus, what knowledge is the focus in technology compared to the other school subjects you've been teaching?

Bella: I'm not really sure how to answer that [silence].

Another way in which the teachers addressed the issue of technological knowledge was to interpret it as something other than knowledge. Flora seemed to have the students' attitudes in mind when she responded to a question about what she finds to be the most important knowledge in technology:

(3) Flora: That technology education is so much fun! And that it's not difficult – and that it's for everyone.

Felicia also had affective aspects in mind and expressed her thoughts like this: (4) 'I think it's a rewarding subject, I believe the students become happy from participating in technology education'.

In view of this, one result of this study is that the teachers are not used to discussing technological knowledge as such, at least not explicitly.

Teachers' descriptions of knowledge – as seen through a theoretical lens

In this section of the results, the researchers interpreted what could be construed as reasoning and arguments about technological knowledge from the teachers' descriptions of their teaching. Since this part takes a philosophical perspective on knowledge, and the content of the teaching is in focus, we applied a theoretical framework based on epistemology, as presented above.

The utterances underlying this analysis were seldom found in parts of the interviews where the questions literally concerned knowledge. Instead, these views of knowledge appeared in parts of the interviews where the teachers were describing their teaching more generally. Overall, we noticed that knowledge from all three traditions in the framework appeared in this data, in particular from the second (technological scientific knowledge) and third (a socio-ethical technical understanding). Descriptions that combined two or three of the traditions were common, although there are also examples where only one appears.

Technical skills

When Agnes described what technological literacy is, she considered the handling of tools to be part of it. Knowledge in the form of technical skills can also be discerned in Denise's description of integrating technology with the school subjects of Crafts and Art:

(5) Denise: . . . about this sketching and drawing, we do that both in Crafts teaching and Art teaching, and in Art I also work a lot with these kinds of design exercises [. . .] in product development, for example, with different packaging.

The integration she described, focusing on design exercises, clearly implies knowledge in the form of technical skills.

Another perspective on technical skills was provided by Bianca, who talked about the students she encountered in grade 5. She described the focus of their previous teaching as being on building bridges, and from her description we understand this as knowledge based on technical skills. She continued to describe how she also focuses on other aspects of technology teaching; about *why* bridges are built (a socio-ethical technical understanding) and *how* they are constructed mechanically (technological scientific knowledge).

Some teachers stated that their teaching primarily focused on knowledge related to technical skills when they were at the beginning of their careers as teachers. This kind of knowledge was described as (6) 'the easiest to tackle' (Celine), but with more experience they also included other perspectives in their teaching. For example, Bianca then aimed to (7) 'put technology into a context', which could be defined as a socio-ethical technical understanding. Notably, Bianca suggested that activities focusing on knowledge about technical skills – (8) 'to build and have fun' – is what the students expect to do in technology class. In fact, as Celine explained, it may be more difficult to inspire the students in other parts of technology education since to build and create is what they expect to do in class.

Technological scientific knowledge

Examples that can be construed as technological scientific knowledge appeared in discussions among teachers from all grades of compulsory school. For example, technical concepts and language were described in the interviews as a foundational form of knowledge in technology education. Frida teaches the youngest children (grades 1–3), and emphasised the importance of understanding concepts:

(9) Frida: That they pick up some factual words [. . .] that they know, for example, what a truss structure is, that they know what a siphon is, that they know what equilibrium is, that they know maybe what friction is [. . .] that is, the wedge. That they acquire even the concepts, that this is important to know even though they're young.

Later on, she also pointed out the importance of understanding how programming works:

(10) Frida: And then I try to show that what text programming looks like [. . .] for example, if you have a dot or comma error, then it becomes a bug. Then you have to start over and do it right, and that accuracy I think is important, that there is an algorithm and what it stands for, as it were.

She strengthened this view in another part of the interview, where she focused on the principles and syntaxes of programming; for example, understanding how a loop works. From her statements, it is clear that *technological scientific knowledge* is the primary focus of her teaching.

Technical solutions constitute another example in this category. Daniella spoke about how she uses the school surroundings to discuss technological solutions with her students. They walk around looking at houses and buildings and talk about how they were built:

(11) Daniella: [W]hy this material was chosen and how you could have done it in a different way, and we look at different buildings from different eras [. . .] and why have sheet metal, copper roofs or tiles been used, or why they . . . yes, all of those things, how to build for stability and how to think when building.

Charlotte has experience of teaching STEM in upper secondary school, and that affects her teaching in grades 7–9. She described a lack of knowledge among her students (12) 'They have major shortcomings in terms of solid mechanics and materials science'. Furthermore, she asserted that there are several connections between technology education and other STEM subjects:

(13) Charlotte: Technology doesn't differ so much from physics, for example. They go hand in hand, but it also differs a bit. Even maths, if they don't know any maths they can't build anything, they can't think right [. . .] gravity, for example, I can talk about gravity in both physics and technology.

Additionally, she described technology as a subject in which students can use knowledge gained from other subjects. She described these connections as the dominant part of the subject. She claimed that her engineering experience has affected her. She values knowledge about materials and mechanics very highly, and, therefore, devotes a large part of her teaching time to this.

Socio-ethical technical understanding

The examples in this category are mainly made up of teachers' descriptions of what they teach as examples of subject content. This category involves knowledge about technology in society. Many of the examples are related to the environment and sustainable development. Charlie said that he teaches about (14) 'what is environmentally friendly and what is not'. Similarly, Celine described an interdisciplinary project focused on the sustainable city. A view of knowledge as a socio-ethical technical understanding emerged, for example, when she explained that she wants the students to (15) 'get an idea of the role that choices play'. Additionally, even in the lower grades the teachers focus on knowledge about sustainable development. One example is Frida, who compared different ways of travelling to school with her students.

In contrast to Frida (excerpt no. 10), who talked about knowledge related to technological scientific knowledge when describing programming instruction, Anthony had another focus. He explained his teaching of programming by describing how he tries to highlight historical, ethical, environmental, and international perspectives in all of his teaching. He mentioned that, when teaching about programming, he might (16) 'talk about self-driving cars, what effect they have, why they mustn't be hacked'. He thus related programming to safety issues and emphasised examples about self-driving cars, to put the teaching in context. This is an example of a socio-ethical technical understanding, in that the way in which programming affects society was given more emphasis than the actual code.

Another aspect of knowledge in this category was history related. Teachers talked about subject content such as driving forces and consequences in connection to technological development. Cars and roads and how they have developed are examples of such content. In relation to the historical perspective, they also talked about how life is now and what will happen in the future, sometimes in relation to sustainable development. Flora related that she talks with her students about consumption and the constant desire to buy new things. Emily gave another example:

(17) Emily: Technology in a historical perspective, but also, we have to get [the students] back to the issue of why we have a wear-and-tear society that's not sustainable. Well, what did we use before? We may not be able to keep producing plastic boxes. What was used to store food in the past and how does it affect the environment? How does it affect the economy? You also include that kind of thinking.

Emily is already teaching her students about the role of technology in society, here in the lower grades. However, this perspective was not shared by all the teachers. Felicia explicitly stated that she thought the social aspects of technology do not come naturally in the lower grades.

Claudia tries to create interest among her students by using, for example, the mobile phone as a starting point in her teaching: (18)'How they're recycled later, what happens when they buy new mobiles, what happens to the old ones [. . .] we talk about Silicon Valley, why it's called that.' Likewise, Flora selects content closely related to her students' everyday life and uses clothes and mobile phones as examples of how technology has changed over time.

Teachers' descriptions of knowledge – as seen through an inductive analysis

In the teachers' descriptions of knowledge, we discerned two overall themes, which complement the deductive themes built on traditions of knowledge presented in part 2. In the inductive themes, the teachers' statements included how the students used knowledge and how they applied their capabilities.

Therefore, an interesting outcome of the inductive analysis in this section is that in the teachers' descriptions there is content that they described as knowledge, although these descriptions are not strictly in line with epistemological definitions or the theoretical framework of technological knowledge. In fact, the teachers here described knowledge in combination with capabilities that are specific to technological education, sometimes also including aspects of attitude, interest or personal characteristics.

One example that illustrates the breadth of the teachers' views of knowledge is when Bianca considered both knowledge and capabilities:

(19) Interviewer: [I]s it possible to say what kind of knowledge is the focus of technology as a subject compared to other subjects?

Bianca: Yes, problems. . . construction, problem solving, I would say, the capability to have the patience to solve something.

Even though the teachers sometimes had difficulties in putting their thoughts about technological knowledge into words, later during the conversations a lot of interesting reflections appeared. There were views of teaching technology and views of the school subject and its opportunities and difficulties. One aspect of technological knowledge is the breadth of the knowledge domain:

(20) Agnes: [. . .] core in biology, there's a core in physics, there's a core in chemistry and there's a small core in technology as well, but I don't think it's as big. And then, it's not so uniform. The subject of technology is so *incredibly* wide, so the knowledge the students graduate with in Sweden, all our graduating students, I think they graduate with a lot of different knowledge, and then I don't mean that one aspect is better than the other, but I think there is a much greater breadth [than in other subjects].

The themes in this part are therefore regarded as reflective of technology education capabilities. Overall, the teachers often talked about these capabilities from a long-term perspective, because they are preparing their students for the future. This could involve general preparations as citizens to make decisions, or more specifically to prepare them for a working life or further study. We have named these themes *Engineering capabilities* and *Civic capabilities*.

Engineering capabilities

In this theme, teachers described knowledge to be the capabilities required to prepare students for future working life and further study, more explicitly for the engineering professions. This theme also includes students' future capability to develop technology. Overall, this theme and its knowledge and capabilities were often process-oriented. The permissive nature of technology was sometimes visible in this theme. However, what characterises this theme is not its knowledge traditions, but how the knowledge is used and practised. Recurring concepts and terms were trial and error, problem solving, a focus on process, to pursue and complete their own work, and cooperation. This theme mainly appeared when the teachers were describing the aim or the nature of technology education, often in comparison to other school subjects.

One expression that frequently recurred in the data was trial and error. Trial and error is a capability that is explicitly mentioned in the curriculum, which is one reason why this expression was common. Nevertheless, it was something that the teachers found important and specific to technology education.

(21) Frida: You can tell [the students] that this is what inventors do. When new things are created you need to try, you have to do and try, and do and try again. And when we teach about [Alfred] Nobel and his development, how he had to use trial and error [. . .] if your profession is inventor or constructor, that's how you work, you don't get it right the first time [. . .].

This exemplifies that, even in these lower grades, the teacher was making connections with technical professions and preparing the students with knowledge and capabilities that are useful in technical careers.

Solving problems is a part of the character of the subject, according to these teachers, and this distinguishes technology from other subjects (de Vries 2016). Emily said that the trial-and-error approach, typically taught in technology education, can also inform other subjects.

Conducting project work was considered to be important subject matter content in its own right, and not simply as a working method for learning other content. Agnes described 'being able to drive something forward, to run a project' as one aspect of what students should learn, something that is unique to technology, but can also be beneficial for life. (22)'Life is a project', she said. Project work was also described as an ability to take responsibility for one's own work. To work independently and run their processes in assignments that are not closely regulated by the teachers was one aspect of students' project work. Driving the work forward was also an important aspect for Bianca:

(23) Interviewer: . . . what knowledge is the focus of technology teaching, compared to other subjects?

Bianca: Problem solving, I would say, to have the capability, to have the patience to solve something [. . .] to be able to get past 'what should I do now?' I think that's very much a focus in technology education, and I can usually relate back to that in mathematics education, to have the grit to solve a problem and not give up [. . .].

She described knowledge in technology education as a capability based on problem solving, being persistent and completing a task.

Another aspect of the core of technology was teamwork. Overall, the teachers talked about being part of a team, cooperating, or working in project groups as important aspects of technology education. These aspects of project work and teamwork were described as ways for the students to become prepared for the future, sometimes explicitly preparing them to become engineers. This is something that Charlotte emphasised, but also Denise:

(24) Denise: . . . engineers today, they exchange experiences and discoveries, this is what you need to teach the students in technology education. They must be allowed to cooperate with others to acquire what is important to become an engineer.

In the lower grades, the teachers described teamwork using words like *cooperating* and *working together*, but in grades 7–9 the teachers talked about *running projects*. They often described their teaching as various projects, which can sometimes be ongoing for two or three months. Consequently, to be able to conduct an assignment or a project is central. Often these descriptions of teamwork were connected to problem-solving assignments, but that was not always the case.

In grades 7–9, the teachers explicitly stated that the process was the focus, more than the product. The *process* was discussed as being part of the knowledge in technology, and as part of the nature of the subject. Anthony and Agnes both claimed that the process is often more important than the product, in their teaching. Alexander agreed with them, and then brought up the concept of 'engineering thinking', which he described as being able to work systematically by trial and error. Furthermore, he also valued brave thinking more than the result and explained that he tells his students they can learn a lot from their mistakes:

(25) Alexander: [T]hat's what technology is all about when you're an engineer, to find new solutions that haven't existed before. So, I feel that's a great learning goal, that they can practise and do things, and then I also give them encouragement to dare to try, be a bit wild and crazy sometimes too – why not? – dare to think outside the box.

The view of technology education as permissive, as a subject in which students learn to think outside the box, was also a recurring theme among the teachers of the younger students.

In summary, the examples of knowledge and capabilities that the teachers describe in this theme are taught in order to prepare their students for a profession. In many cases, engineering is explicitly mentioned as an example, even by teachers teaching the youngest students.

Civic capabilities

This theme is about teachers' descriptions of knowledge as something that is required to prepare students for life in a technical world. They teach them knowledge and capabilities to become well-informed citizens. In this theme, the teachers sometimes referred to how they prepare their students for the future by giving them a solid basis in technology education, for the students to become well-informed future citizens who can make decisions about technology. This includes the capability to gain a holistic perspective on technology. Recurring concepts and terms in this theme were basic understanding, technological literacy, the role and consequences

of technology, and systems thinking. This theme is characterised by the students' ability to use different kinds of knowledge to conduct analyses and syntheses. It mainly emerged when the teachers were discussing the aim of technology education and when they were describing its character. In some ways, the boundary between the themes *socio-ethical technical understanding* and *civic capabilities* is not entirely clear; there are similarities between them. However, what distinguishes civic capabilities is the holistic approach and the capacity to put knowledge (from the socio-ethical tradition or other traditions) into a context. Also, there are more normative aspects to civic capabilities than to a socio-ethical technical understanding.

Technological literacy is a concept that was sometimes explicitly mentioned by the teachers, mainly among those teaching the higher grades. These utterances seem to approach technological literacy at two levels. Firstly, the teachers talked about a kind of general education. Agnes described technological literacy as a general form of wide-ranging technological knowledge: (26)'I'm looking for technological literacy, not specialised knowledge.' Furthermore, she explained it as being able (27)'to take a stand in an informed way.' Carl believed that technology education has an important role to play in giving everyone a foundation in technical questions and decisions, such as the energy question, because (28)'every citizen actually needs the opportunity to form an opinion.' Celine stated:

(29) Celine: [C]ompulsory school has the task of providing students with a general education. Of course, we should evoke interest in those who want to study technology, that's good, but I think another very important thing is to make sure that all [students] who don't choose to study technology are not fooled by all the damn drivel that pops up.

Secondly, Anthony summarised technological literacy as a holistic perspective or capability. Agnes connected technological literacy to systems thinking:

(30) Agnes: I would like to agree with the thing about systems thinking that you [another focus group member] mentioned, when it comes to literacy, and that's the ability of systems thinking. It's the basis for being able to reason about ethical issues, consequences, at different levels and in different dimensions. It's important, I think.

In lower grades, the teachers seldom mentioned technological literacy or similar terminologies in particular. This is not surprising, taking the age of the students and the curriculum into account. Nevertheless, there are excerpts indicating that teachers in lower grades also prepare their students to become technologically literate. In their descriptions, there were examples of both sustainability and historical perspectives on technology, in line with a holistic approach to technology. As observed in part 2, the historical and sustainability perspectives were salient in the interviews with teachers in grades 1–3. In this theme, the excerpts additionally show how teachers hint at the holistic perspectives of technology, as part of preparing students to make decisions about technical questions and problems. Emily, (see excerpt no. 17) focused mainly on knowledge interpreted as a socio-ethical technical understanding. But we also interpret an ambition to teach students how to make decisions in their everyday lives, at a level suitable for children.

In some situations, history was utilised to help students understand technology today and how technology is connected to society and the environment. Denise talked about studying technology in a context, and not as separate objects. Carl and Bianca talked about students becoming future citizens, who need to make good decisions. Carl described technology education as enabling people to:

(31) Carl: . . .understand the technology around us, how it affects us and society, and how technology, technical systems are created and evolve and so on [. . .] we want students to be able to make well-balanced decisions, we want them to somehow understand what happens when Google owns more and more of our information.

Discussion

The aim of this study is to examine how teachers discuss technology education, with a particular focus on how they talk about technological knowledge

One finding is that the teachers were not used to discussing or expressing their thoughts about technological knowledge. Typically, the teachers' first reactions when asked to talk about knowledge was to say that they were uncertain about or unfamiliar with this kind of discussion. Nevertheless, the analysis of the focus group interviews revealed many statements that were in fact about knowledge, although this was not always made explicit. Thus, when discussing technology education and knowledge in the focus groups, and when the teachers were asked to describe their teaching and their views on technology education, interesting aspects of technological knowledge and related phenomena, such as capabilities, were revealed.

When applying an epistemological framework as an analytical tool, numerous examples of technological scientific knowledge were identified. The teachers mentioned terms like *truss constructions* and *materials*. This might be because this kind of subject content is the easiest to describe and measure. Conversely, examples of knowledge as technical skills may have been more difficult to describe in words because this knowledge is often expressed in actions rather than words (Mitcham 1994; Nordlöf et al. 2021). We had expected to find more examples of technical skills, in view of the results from the Swedish Schools Inspectorate Report 2014, which showed that in Sweden a central focus of technology education is on doing and making (Skolinspektionen 2014). In this study, knowledge in terms of technical skills mostly appeared when the teachers were describing how they had developed professionally; over the years, they have gained more knowledge about technology education themselves and have developed from focusing their teaching mainly on technical skills towards a socio-ethical technical understanding.

An inductive analysis revealed two themes in how the teachers formulated their views about knowledge in technology education. The analysis of their utterances about knowledge indicates that their descriptions were not strictly in line with philosophical frameworks or definitions of technological knowledge. Rather, they described knowledge in combination with specific technological capabilities. In other words, a broader view of what the students are to learn, which also includes capabilities and sometimes more attitudinal dimensions.

The first theme focuses on the capabilities of technical professions and the second on forming citizens, in our terminology *engineering capabilities* and *civic capabilities* respectively. Examples of the three categories of knowledge from the deductive analysis (technical skills, technological scientific knowledge, and socio-ethical technical understanding) were found to be related to the two themes in the inductive analysis. The most common examples of knowledge related to engineering capabilities were *technical skills* and *technological scientific knowledge*, but it was not exclusively this knowledge. The knowledge related to civic capabilities were often examples of *socio-ethical technical understanding*, but also sometimes characteristic examples of *technological scientific knowledge*.

The teachers' broad views of knowledge in technology education are probably natural because they work in a classroom context where knowledge is never considered in isolation, but instead the students are supposed to learn in a multidimensional context using different methods and in different situations, often combining knowledge with capabilities. In the focus group interviews, the teachers therefore seldom talked about technological knowledge separately from the context. More specifically, they were probably influenced by how the subject is presented in the curriculum, including how it is presented not only in relation to knowledge but also in terms of purpose, core content, and various capabilities. Other recent Swedish interview studies have also shown that teachers find it difficult to separate the aspects of content, abilities, knowledge, and purpose (cf. Brink, Kilbrink, and Gericke 2021; Fahrman 2021) when talking about technology education.

Civic capabilities, overall, were more visible among the teachers in the higher grades. Interestingly, however, the teachers talked about preparing their students to become engineers already in the lower grades. The engineering component of technology education frequently recurs in the literature. Most of the recurring terms and concepts in the category of engineering capabilities are also common in the more specific technology education literature. Barlex (2009) mentions both problem-solving and student teamwork in the English school subject of Design and Technology. In a Swedish study, teachers found it crucial to develop problem-solving skills in technology education (Fahrman et al. 2020). Both systems thinking and technological literacy, two terms found under civic capabilities, are described in the literature as general abilities of being able to see the 'big picture', or technology in context (Jenkins 1997; Lesh 2006; Ropohl 1997).

In terms of the implications of our study, being aware of different kinds of technological knowledge can scaffold and possibly help a teacher to develop in her profession (cf. de Vries 2016). One concrete subject component that was often referred to by the teachers in the focus groups is programming. In the results, two different ways of approaching programming are visible. Frida focused on understanding the code and the importance of getting it right, whereas Carl emphasised the students' understanding of how autonomous vehicles, as examples of programmed technology, affect the world around us. Consequently, teaching programming can look very different depending on what kind of knowledge is the focus. Thus, when a teacher has a broad conception of technological knowledge, she may also gain a more multifaceted perspective on the subject content, and thus a better grasp of her teaching in technology education.

Finally, the results presented in this article constitute yet another piece of the puzzle for understanding technology education and the subject of technology. In the literature, the epistemology of *technology* is rather well examined. The epistemology of *technology education*, however, has been less well investigated and in order to gain more knowledge about it, it is important to study the voices of the main performers in the teaching of the subject. By combining the three-part epistemological framework with inductive analysis of the teachers' descriptions of technological knowledge, two different but equally valid perspectives on knowledge in technology education were identified, one based on theoretical definitions and the other on teachers' ideas of knowledge. An amalgam of these two perspectives may point us towards what exactly makes technology education knowledge unique. In the literature, this has been termed, for example, 'engineering thinking' and is described as a special competence or understanding (Fahrman et al. 2020; Fahrman 2021). The results of this study point to the content of such an understanding or competence. This is illustrated in Figure 1, where the three knowledge categories (technical skills, technological scientific knowledge, and socio-ethical technical understanding) form the three sides complemented by the two capabilities (civic capabilities and engineering capabilities) that form the top and bottom of a prism (cf. DiGironimo 2011). They all enclose the unique character of technology education, here called *technology education competence*, with regard to a multi-dimensional view of competence (Le Deist & Winterton, 2007). Consequently, this concept does not capture the competence of the teachers (compare to PCK, e.g. Shulman 1987), but instead illustrates the knowledge content and the capabilities that make up the school subject of technology education and contributes to creating the nature of the subject.

Limitations

This study employed a qualitative research approach, so the findings should not be thought of as generalisable. Nevertheless, the participating teachers do reflect multiple teacher backgrounds and educational levels, and we suggest that the resulting model of technology education competence may be useful for illustrating the amalgam of central knowledge content and capabilities that make up the school subject of technology.

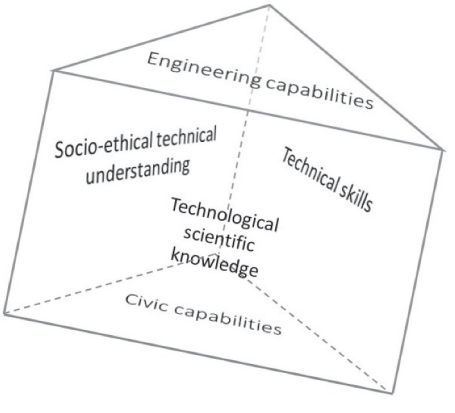

Figure 1. Technology education competence.

In studies employing focus group methodology, the researcher takes a passive role while participants to a large extent drive the process through their interactions. Hence, although the researcher may guide the discussions to some extent through the use of an interview guide, it is not possible to ensure that the groups cover an intended range of topics.

Conclusions

This study contributes to our understanding of teachers' perspectives on technological knowledge. Their perspectives are important, since it is the teachers that interpret curricula and teach students. Therefore, theoretical studies of knowledge in technology are not enough, because adding how teachers view knowledge gives a more realistic overall picture of how those performing technology teaching perceive knowledge in the subject. The findings indicate that the participating teachers have a broad conception of the term knowledge. Even though the teachers were uncertain and not accustomed to discussing such questions, many examples of knowledge were found in their discussions. The teachers talked about technological knowledge in terms of preparing students for their future adult life, regarding both technological proficiencies and technological literacy. When applying the epistemological framework of knowledge in technology education, more traditional aspects of knowledge were also found. The results reveal examples of all three knowledge categories: technical skills, technological scientific knowledge, and socio-ethical technical understanding. Two further categories were found in the inductive analysis, civic capabilities and engineering capabilities, which demonstrate that the teachers have a broad view of knowledge that also includes capabilities, that is, the ability to perform or act out technological knowledge in a relevant context.

As a consequence, the teachers' perspectives on knowledge in technology extend beyond traditional epistemological frameworks, which is an important finding that could be elaborated further in future research. The teachers also included capabilities in their descriptions of knowledge. To some extent, this may be because the curriculum includes capabilities, but it is probably also because these teachers meet students in a classroom context where knowledge is not neatly separated from other aspects of teaching. The overall results were presented and summarised in the model of *Technology education competence*, a prism whereby the teachers' views and the relation between knowledge and capabilities is visualised.

The teachers' views might be helpful in gaining a deeper understanding of the epistemology of technology education, since they mirror the teachers' conceptions of which knowledge components are important for educating their students to become citizens and engineers in the future. The results of this study also point to important aspects of the nature of the subject, which might lead to reflection about what knowledge should be considered of value in the future, regarding research but especially development of curricula.

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