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Experienced technology teachers' teaching practices

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Abstract
Teachers' teaching practice plays a key role in the learning process of pupils, and for teaching to be successful, teachers must have knowledge in many different fields. This obviously also applies to teaching the subject technology. However, lower secondary school technology education in Sweden has reportedly been described in terms of teaching not following the curriculum along with widespread uncertainty among teachers regarding how to design their teaching practices. To address this national challenge, we need to understand the existing technology teaching practice. The purpose of this study is therefore to explore the considerations experienced technology teachers make. The study is based on interviews with technology teachers who work in lower secondary school (13–15-year-old pupils). The collected data consist of teacher's statements regarding their own expertise and teaching practice. To visualize the described teaching practice we have analysed collected data through the lens of pedagogical content knowledge (PCK). The results show both similarities and differences in the teachers' descriptions. Speaking in terms of PCK, the purpose and teaching focus expressed by the respondents, framed within the category 'Orientations to teach technology', vary considerably. However, regarding 'instructional strategies', the consensus among those experienced teachers is striking. Experienced technology teachers' teaching practices are proven to provide valuable information about the subject's potential, and the findings offer a basis for the future development of the subject of technology as well as future teacher education and professional development courses.

Keywords Technology education · Experienced teachers · Teachers' practice · PCK · Lower secondary school

Introduction

Teachers play the key role in the learning process of pupils, and for teaching to be successful, teachers must have knowledge in many different fields. Because the contents of what the pupils learn much depends on the teachers' knowledge and skills, it is of interest to understand more about the different competencies a teacher might have (Håkansson and

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Sundberg 2012; Nordenbo et al. 2008). In Sweden, a debate about teachers' skills and subject knowledge has taken place, creating the need for further insight into teachers' teaching practice. This also applies to the subject of technology, where the debate has focused on aspects such as the lack of subject teachers with adequate training and skills, how the purpose and content of the subject is not clear to the pupils and how classroom practices are not aligned with the curriculum (Skolinspektionen 2014; Teknikföretagen and Cetis 2012). To further develop the knowledge of teachers' classroom practice, this study aims to capture the knowledge teachers' demonstrate in the process of teaching technology.

The current article presents the findings from a study of technology teachers' reflections about their teaching practices and focuses specifically on the teachers' planning of content and pedagogical strategies.

The respondents partaking in this study are experienced lower secondary school teachers. All are certified teachers with many years of experience teaching technology and other subjects. New insights into teachers' practices can create new perspectives in the ongoing debate about technology teachers' knowledge base (Skolinspektionen 2014; Teknikföretagen and Cetis 2012). Surveying the knowledge that they use in their technology teaching sheds light on subject-specific practices, thereby adding important pieces to the development of technology teaching education.

Background

The subject of technology in Sweden

Technology is mandatory for grades 1–9 in Swedish compulsory schools and has been so since the early 1980 s. The latest curriculum, issued in 2011 (Skolverket 2018/2011a, 2018/2011b) has a stricter design than previously by establishing knowledge requirements for school years 6 and 9 and the abilities that pupils are expected to develop. These subject-specific abilities are the same throughout the 9 years of compulsory schooling and are to be practised in connection to a defined core content, specified for years 1–3, 4–6 and 7–9. The knowledge requirements, aimed to guide grading, are presented for school years 6 and 9.

The abilities associated with the subject of technology are as follows:

- Identify and analyse technological solutions based on their appropriateness and function
- Identify problems and needs that can be solved by means of technology, and work out proposals for solutions
- Use the concepts and expressions of technology
- Assess the consequences of different technological choices for the individual, society and the environment
- Analyse the driving forces of technological development and how technology has changed over time (Skolverket 2018/2011a, 2018/2011b)

For pupils to develop the core contents of the subject of technology, as stipulated in the curriculum, a number of areas must be covered by the teacher. This includes mechanics, materials, electronics, automatic control, technical development processes and how technology is related to science, society at large and the fine arts (Norström 2014).

In contrast to the subject of technology in, for example, England and Scotland, the Swedish technology subject does not include wood and textile work (Norström 2016). In the curriculum for Swedish compulsory school, art and crafts are separate subjects. Both are mandatory and have their own syllabi. Wood, metal and textile work is included in the crafts subject (Skolverket 2018/2011a, 2018/2011b) and is not explicitly mentioned in the technology syllabus.

Even though technology has been a mandatory subject for more than three decades, there is still no consensus regarding the contents or practices of the subject (Jones et al. 2013; Norström 2014; Skogh 2006). This has resulted in many teachers being insecure in teaching the subject of technology (Nordlander 2011; Teknikföretagen 2005) and varying levels of knowledge among pupils (Bjurulf 2008; Skolinspektionen 2014). Several publications (e.g. Skolinspektionen 2014; Teknikdelegationen 2010; Teknikföretaget and Cetis 2013) have reported shortcomings related to teachers' difficulties in following the directions outlined in the curriculum and their use of classroom activities that do not contribute to the pupils reaching the desired learning outcomes. The Swedish School Inspectorate (Skolinspektionen 2014) expressed concern that the purpose and content of the subject of technology are not clear to pupils. This naturally influences the teaching practices as well as pupils' learning. These difficulties may, according to Fahrman et al. (2015), be seen as a consequence of a curriculum that is too broad and extensive, as well as insufficient subject training or lack of time.

The School Inspectorate (2014) concludes that the subject of technology has a secluded place in Swedish schools. Technology is the most recently added subject to the Swedish compulsory school curriculum and has had a shared time schedule with the science subjects. This has, however, recently been changed. From autumn 2018 technology will have its own time schedule of 200 h, which are to be shared from grades 1 to 9 (Skolverket 2018/2011a, 2018/2011b). As opposed to what is required for further studies in the science subjects, pupils leaving compulsory school and moving on to higher studies do not need to have a passing grade in technology.

Technology teachers in Sweden

The requirement for diplomas of certification for teachers was introduced in the Education Act in 2010. The aim of certification is to increase the quality of Swedish education, raise the status of the profession and clarify what a teacher is qualified to teach. Obtaining a certificate requires a degree in teaching. It is the content of the degree that governs the teaching diploma. The annual report from the Swedish National Agency for Education (Skolverket 2015) showed that between 38% and 60% of technology teachers, depending on the grade they teach, are formally qualified and licensed to teach technology. According to Hartell et al. (2014), non-qualified teachers, to a greater extent than qualified ones, state that they lack the necessary competencies required for teaching technology. This lack of qualified teachers not only affects how technology is perceived and taught; it also affects the content and practice of the subject (Norström 2014; Skogh 2006; Teknikföretaget and Cetis 2013), the pupils' achievements (Nordlander 2011; Skogh 2006) and the teachers' insecurity about their teaching (Nordlander 2011; Teknikföretagen 2005).

In a study of five technology teachers' understanding of the subject, Bjurulf (2008) found that their interpretations of the subject's purpose and their choices of subject matter and teaching methods varied significantly. One of the respondents claimed that the purpose of technology education in school was to learn everyday skills. Another said that the purpose was to prepare the pupils for future careers in engineering. A third stressed a technological understanding as being essential for understanding the natural sciences. According to Bjurulf, this diversification affected what abilities pupils could develop in technology. The results also indicated that technology was taught in different ways depending on the teacher's educational background, the physical learning environment and the size of the pupil group.

Teaching

The classroom is an arena in constant change, one where teachers develop their educational skills over time. Their competencies are complex and multifaceted. Researching, exploring and understanding teachers' knowledge and skills are also complex. Studies in this area have had different starting points and have used different methods, depending on the focus of the research. Areas such as subject content, educational goals and objectives, pedagogy, curriculum, context and pupil skills are among the studied themes (Park and Oliver 2008; Verloop et al. 2001).

What leads to successful teaching is a broad theme, including the study of teachers' competencies, abilities and commitment. Research (Håkansson and Sundberg 2012; Nordenbo et al. 2008) has shown that there are several skills teachers need to support pupils' knowledge development. Leadership in educational work is one area, but subject knowledge and the ability to vary teaching methods are also important. Knowledge of classroom interactions and group processes and the ability to handle them are also crucial.

According to Jones and Moreland (2004), pupils learn most efficiently when their teachers have a wide range of different qualities and competences. These include matters such as: having a broad understanding of the curriculum's aims and objectives, having a wide range of pedagogical strategies, providing effective feedback and having sound content knowledge. Cowie et al. (2008) stated that when teachers teach science and technology well, they use pedagogically powerful ways to represent the content to their pupils. At the same time, they consider their pupils' preconceptions and understandings. Effective teachers are able to bring to mind, select and use the most appropriate examples, metaphors, illustrations, activities and demonstrations that help promote their pupils' understanding. They can clarify the subject matter so that everyone can learn.

Aim and research question

Considering the above information, the question of identifying the qualities and competencies of importance to technology teachers has become increasingly crucial. Experienced technology teachers' teaching practices provide valuable information about the subject's potential and may form a basis for future teacher education and professional development courses for teachers.

The aim of the current study is to develop the understanding of the specific practices that experienced secondary school technology teachers use when they teach technology.

The research question put forward in this paper is:

> What aspects of pedagogical content knowledge do experienced technology teachers express?

Theoretical framework

In line with the research on teaching described above, successful teachers have a special blend of content knowledge and pedagogical knowledge, or—*pedagogical content knowledge* (PCK), which is developed over time. This form of professional knowledge, first formalised by Shulman (1986, 1987), is topic-specific, unique to each teacher and essentially gained through teaching practice (Williams et al. 2012). Shulman conceptualised a teacher's professional knowledge as the knowledge formed at the intersection of content and pedagogy. It is demonstrated by teachers through their understanding of how a particular subject matter or issue is organised, represented and adapted to the diverse interests and abilities of learners and then used to engage learners during instruction (Shulman 1987). Ideally, pupils can grasp the ideas being taught while the integrity of the scientific ideas are maintained (Cowie et al. 2008). Park and Oliver (2008) described PCK as involving teachers' understanding of how to help a group of pupils understand a specific subject matter using multiple instructional strategies, representations and assessments. Shulman's (1986, 1987) ideas about teachers holding unique knowledge bases caught the attention of many researchers, particularly in the field of science and mathematics education (Gess-Newsome 2015).

Researchers have explored specific parts of the PCK model in relation to specific subjects, to teachers' professions or to a pupil's learning in relation to one particular knowledge base (Ball et al. 2008; Ellis 2007; Fernandez 2014; Gess-Newsome 1999; Grossman and Richert 1988; Jones and Moreland 2004). Grossman (1990) made important contributions to the development of the PCK concept by providing a more detailed model, dividing teachers' knowledge into well-defined categories. From Grossman's revised PCK model, researchers such as Carlsen (1999) and Magnusson, Krajcik and Borko (1999) further developed and explored the components that make up PCK. The oft-cited model of Magnusson et al. (1999) was developed to study the teaching of science subjects; their model specifies PCK as the conceptualisation of a transformation of knowledge from different knowledge bases, which are all important for teaching a subject. In their view, an experienced teachers' PCK is the result of the transformation of several types of knowledges.

Different ways to interpret and understand PCK have been formed over time and resulted in a divergence in definitions, models and data collection methods. Therefore, key researchers within the PCK field saw a need to discuss the limitations of PCK and work to strengthen the concept by establishing consensus around the PCK construct. Thus, at the 2012 PCK Summit, researchers met to discuss PCK, with an aim to reach consensus concerning the PCK model (Gess-Newsome 2015). The new model combines features from different earlier suggestions and has a larger scope, which has led to it being more complex than previous versions. Certain new features have been introduced into PCK, so-called *amplifiers* and *filters*, which represent teachers and pupils' beliefs, orientations, prior knowledge and contexts.

PCK in technology education

Most research done around PCK originates within the science subjects. However, Williams and Lockley (2012) have studied the development of PCK among both science and technology teachers; they state that there are differences between learning areas, which lead to differences in how PCK can be interpreted and used in the respective subjects. These differences are founded in the historical conceptual thinking underlying the learning areas, the way that the subjects are taught and the traditional backgrounds of teachers in the subjects. Science has a well-established epistemology, leading to an established organisation of knowledge into accepted topics of inquiry. Technology, on the other hand, has a shorter history, both as a school subject and as a philosophical enterprise, wherefore no commonly agreed upon epistemology exists (Williams and Lockley 2012). According to Jones et al. (2013), knowledge about PCK in technology is key to the subject's future development; they emphasise that the construction of a knowledge base for teachers is central for the efficient teaching of technology.

In technology education research, studies focusing on teachers' PCK are relatively rare (Williams et al. 2012). However, there are some examples. Jones and Moreland (2004) introduced a model of PCK for technology teaching with seven characteristics that are important for effective teaching. A technology-specific planning framework was developed to articulate the learning outcomes and enhance teachers' knowledge. Williams et al. (2012) explored early-career teachers collaborating with senior teachers using a content representation document (CoRe). The purpose was to further develop the early-career secondary teachers' PCK in technology. Rohaan et al. (2012) focused on the development of teachers' knowledge in technology in primary school. They concluded that teacher training should focus on the development of the teachers' subject knowledge as well as PCK; doing this will positively affect teachers' confidence and attitudes towards teaching the subject.

In previous PCK-related technology education studies, experienced teachers have not been studied in depth (Williams et al. 2012). Instead, the research has mainly focused on beginner teachers and teacher students. The current study is an attempt to increase our knowledge on experienced teachers.

Model used in this study

Our intention is not to describe the teachers' PCK but rather to use PCK as a tool for analyses of collected interview data. That being said, the interviews do not provide an overall picture of the teachers' PCK. When choosing a lens that could allow us to obtain a holistic view on how technology teachers find their practice, it was concluded that a suitable model for the analysis of data was to use the model by Magnusson et al. (1999). Specifically, the category 'Orientations towards teaching' in Magnusson et al.'s model fit our purpose in highlighting the teachers' different views on their teaching. 'An orientation represents a general way of viewing or conceptualizing [technology] teaching. The significance of this component is that these knowledge and beliefs serve as a "conceptual map" that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks … and the evaluation of pupils learning' (Magnusson et al. 1999, p. 97).

The choice was not obvious; the revised PCK model from the PCK Summit in 2012 (Gess-Newsome 2015) has a more complex setting and takes more into account when describing teachers' PCK, but it does not focus on our questions in the same way. The same applies to the PCK model by Jones and Moreland (2004). Their model has a focus on primary school teaching and on the development of teachers' PCK. Our analysis frames the teachers' views of their teaching practice, not what parts of PCK they should develop.

Magnusson et al. (1999) model has five categories. As their model focuses on science education, the categories have been modified for technology education purposes:

(a) Orientation towards teaching technology
(b) Knowledge of the technology curriculum,
(c) Knowledge of pupils' understanding of technology,
(d) Knowledge of instructional strategies for teaching technology and
(e) Knowledge of assessment in technology.

Orientations towards teaching technology

In the model, this component describes teachers' insights into how components b–e interact, relate and form a whole that is greater than the sum of its parts. According to our interpretation of Magnusson et al.'s model, 'Orientations towards teaching technology' is an overarching set of attitudes towards technology and the subject of technology. By having 'knowledge of curriculum', 'knowledge of pupils' understanding' etc. as separate categories, its foundational nature can be made clear.

How to interpret this first component has been widely discussed and has differed among the model's users (Fernandez 2014; Gess-Newsome 2015). Users have perceived the relationships between the 'orientations…' component and the others in different ways: Are the other components parts of 'orientations…', and if so, in what way and to what extent? In this study, teachers' purposes, prior knowledge and contexts were included.

Knowledge of the technology curriculum

This component contains teachers' knowledge of the mandated goals and objectives of the subject adapted to specific contents and the progression throughout the 9 years of compulsory schooling. This includes being acquainted with specific curricular programmes and materials (cf. Magnusson et al. 1999, p. 103 f.).

Knowledge of pupils' understanding of technology

Teachers need knowledge of pupils' understanding to help them develop subject-specific technological knowledge; this includes knowledge on pupils' difficulties in understanding specific concepts as well as their prior knowledge, variations in understanding, how knowledge is developed and so forth (cf. Magnusson et al. 1999, p. 104 ff.).

Knowledge of instructional strategies for teaching technology

In Magnusson et al.'s (1999) model, the component 'Knowledge of instructional strategies' is divided into *subject-specific strategies* and *topic-specific strategies*. The topic-specific strategies include two sub-components: *activities* and *representations*. At its core, technology is an activity-oriented subject. Therefore, the dividing line between *subject* and *topic* becomes blurred; it is often difficult to differentiate the methods from the content. In the current study, the two categories are united into 'knowledge of instructional strategies for teaching technology', with activities and representations as sub-components (cf. Magnusson et al. 1999, pp. 109–115).

Activities correspond to teachers' knowledge of the teaching methods that can be used to help pupils comprehend specific concepts or relationships (e.g. demonstrations, investigations, experiments, assignments and examples). This also includes teachers' knowledge of how specific activities can be used for certain purposes, that is, the extent to which an activity presents, signals or clarifies important information about a specific concept or relationship.

Representations correspond to the way teachers illustrate content and enable pupils to develop their knowledge and understanding. It refers to teachers' knowledge of the ways to represent specific concepts, relationships or principles to facilitate pupils' learning, as well as knowledge of the relative strengths and weaknesses of particular representations. Representations include (but are not limited to) illustrations, simulations, examples, models, analogies and metaphors.

Knowledge of assessment in technology

Methods for assessment need to be suitable for the content and the specific subject's epistemological traditions. This component refers to teachers' knowledge of *why* (purpose and knowledge development), *what* (assessable contents) and *how* (methods) to assess various aspects of technological knowledge (cf. Magnusson et al. 1999, p. 108 f.).

Included in this component is knowledge about summative and formative assessment, from formal testing to feedback during classroom work.

Method

Data were collected through semi-structured interviews with experienced technology teachers and analysed using the model described above.

Respondents

The participating teachers responded to an invitation sent through e-mail to their school principal and a letter explaining the intended research. The schools had previously partaken in a school development project, Boost for Technology (Zupanc, et al. 2013), instigated by the local university. Four teachers were chosen as interviewees, each of whom had different backgrounds and worked at different schools. They were all licensed to teach technology in lower secondary school (13–16-year-old pupils) and had several years of experience.

Three of the teachers were trained to teach science and/or mathematics in addition to technology. One of them had a degree in engineering and used to work as an engineer before becoming a teacher. Another respondent taught crafts in addition to technology. Their backgrounds and qualifications are summarised in Table 1.

Data collection

Data were collected through semi-structured interviews (Kvale 1997). The questionnaire used mainly revolved around issues of practical and theoretical aspects of teaching technology, how the teachers planned and executed lessons and the subject content of their lessons. The assessment and knowledge of pupils' learning were discussed in relation to those aspects and not explicitly asked for. Follow-up questions were used for clarification.

Table 1 The respondents

Name (pseudonym)	Gender	
Adam	M	M. Sc. in Engineering, qualified to teach mathematics, physics, chemistry, biology and technology. Thirteen years of teaching experience Works in a large school with pupils aged 6 to 16 (grades K to 9), situated in a middle-class suburb
Bertil	M	Qualified to teach crafts, and technology. Twenty-seven years of teaching experience in total, 10 years as a technology teacher Works in a small school with pupils aged 12 to 16 (grades 6 to 9), situated in a middle-class suburb
Cesar	M	Qualified to teach mathematics, physics, chemistry, biology and technology. Sixteen years of teaching experience Works in a small school with pupils aged 6 to 16 (grades K to 9), situated in a lower middle-class suburb. Swedish is a second language for a most of the pupils
Dagny	F	Qualified to teach physics, mathematics, and technology. Sixteen years of teaching experience Works in a medium-sized school with pupils aged 13 to 16 (grades 7 to 9), situated in an upper middle-class suburb

Prior to the interview, each respondent was informed about the overarching purpose of the study and of their rights as interviewees according to the rules of the Swedish Ethical Review Act (2003).

The interviews were conducted at the participating teachers' respective workplaces. The interviews lasted between 35 and 50 min and were audio-recorded in Swedish. The recordings were later transcribed in Swedish by the main author.

Analysis of data

The analysis process started with multiple readings of the transcripts. The data were then coded using the five categories from the PCK model of Magnusson et al. Each reading focused on one of the different components of the model. Findings from each of the readings were then sorted by component and respondent. They were re-read by two of the authors to clarify the findings. The descriptions of the five components were frequently checked against the coded material. The finished analyses are presented below (Fig. 1).

Limitations of study

There are limitations of particular interest to the current study. Firstly, the purpose of the study is to describe and discuss teaching practices in technology using qualitative methods. Due to the limited number of respondents, generalisations of teachers' statements should be made with the utmost caution. Also, only one method of data gathering is used: interviews with experienced technology teachers. Pupils' opinions and experiences are beyond the scope of this study.

Thirdly, analysing technology teachers' PCK is particularly difficult because of the combination of the broad subject contents and the possible variation in the interpretation of

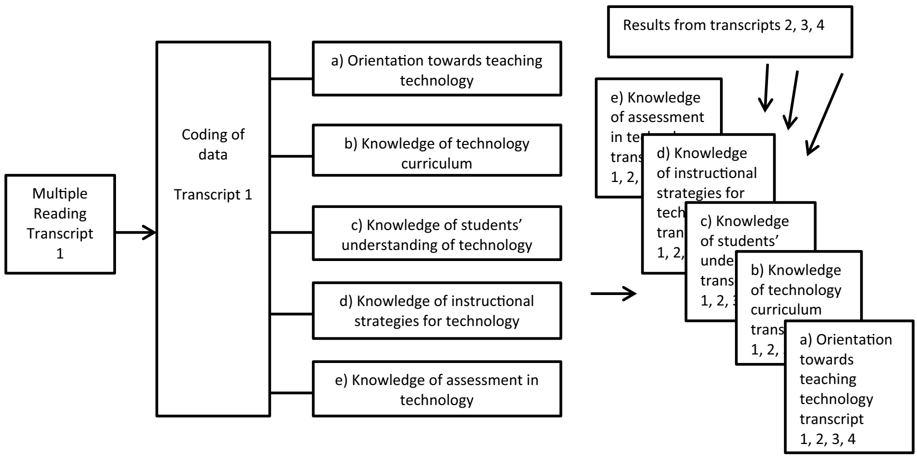

Fig. 1 Process for analysis of data using the PCK model (based on Magnusson et al. 1999)

PCK. The model is difficult to interpret and many variations have arisen. This has been addressed in later discussions about the PCK model (Gess-Newsome 2015). On the other hand, the use of the model opens up for studies in under-researched areas as the current study did not restrict the exploratory approach of data collection and analysis.

Results

This section presents the results from the analyses and findings, which are presented in the same order as the in modified version of Magnusson et al.'s model. Because the teachers mostly spoke of how their teaching was conducted, the results describe statements focusing on planning, teaching and how the teachers described their teaching practices.

Orientations towards teaching technology

The analyses concern the respondents' answers about the holistic view concerning their technology teaching (for 13–16-year-old pupils). This includes their teaching focus and the purpose of the subject of technology.

Adam describes how he wants to convey a teaching approach that, in connection with the design process, mediates an 'industrial mind-set'. By this, he means that there is a work process that he wants the pupils to master. It deals with design, continuous evaluation and finding errors as early as possible when issues are easy to eliminate through change and redesign. To instil this mind-set, or way of thinking, is an overarching goal for Adam's technology teaching. For him, to tick each item on the core content list is a way to approach the industrial mind-set.

Bertil's goals are somewhat different. He wants to increase pupils' interest in technology, to make them understand how fascinating and interesting it can be. According to Bertil, this goal can be reached by emphasising practical activities, such as experimenting, designing and making. Technology should be fun and challenging. He claims that he succeeds in convincing nearly all pupils that technology is exciting.

Neither Cesar nor Dagny express such strong opinions about the overarching purpose of the subject of technology or go beyond the writings in the curriculum when discussing the subject's contents. According to Cesar, he feels obliged to create opportunities for all pupils, no matter their level. Dagny stresses the problem-solving skills that can be developed through the subject of technology as being the most important.

Knowledge of the technology curriculum

The respondents describe how they plan and design their lessons and projects in connection to parts of the core content and abilities. They use different documents to communicate the purpose, procedures and results of different tasks and assignments. These include (but are not limited to) a description of contents, intended learning outcomes, relevant skills and assessment criteria.

Adam says:

> Yes, the pupils are familiar with them, the five different abilities we have in the subject of technology. And they get them in all subjects, the same kind of student sheets [that describe the desired outcomes]. Though technology differs, [it is] not really like science, it differs pretty much there. […] We are going on about [the abilities] all the time, and the pupils are used to it. We are not sure if we are doing the right thing, but we have found it to be a way that is useful for us. And the pupils know that I've documented throughout the year. You can find out how each ability is documented, and in the spreadsheet you can go back in time when it is time for grading.

All respondents describe how they plan a new theme either starting from the content, or from an activity. When starting from the content listed in the curriculum, they try to find relevant activities and make it clear how these elements are connected to the curriculum and modify them if necessary.

The respondents believe in participating in competitions, such as First Lego League (FLL) (an international competition where pupils design, build and program Lego robots), Future City (planning a sustainable city and building a physical model of it) and innovation competitions. These competitions are designed to be aligned with the curriculum. The benefit of participation is that the pupils are motivated to put in extra effort and also that the competitions encourage interdisciplinary work. Dagny says:

> Competitions, we think, are incredibly good. We think that they are good projects; there is a good setup to plan lessons from, and you do not have to plan everything from scratch.

Adam explains that his pupils have widely varied levels of knowledge when he first meets them in the seventh grade and that they often lack manual skills. He finds it difficult to uphold a vertical curriculum: building on what pupils have learnt in previous grades and using themes with increased levels of difficulty and complexity. Furthermore, he finds that pupils have difficulty understanding subject content areas and that therefore the teaching tends to address only parts of the subject's content. The other teachers also talk about how they find it difficult to cover the complete core content. Cesar says that he only teaches a third of the core content because of a lack of time, the pupils' difficulties with the Swedish language and resulting lack of comprehension. He justifies his choice of reducing the contents by always making sure that he has provided ample opportunities for pupils to develop all five of the technology subject's designated abilities. He also tries to connect technology with the science subjects whenever possible.

Knowledge of pupils' understanding of technology

The teachers believe that trying out methods and making mistakes are important steps in developing pupils' understanding. This allows the pupils to discuss, evaluate, redesign and improve their designs. The teachers note that combining the theoretical parts with practical activities is of utmost importance for developing pupils' understanding of a specific subject matter.

All respondents stress the importance of using proper words and concepts. For Cesar this is particularly important, and he tries to support his pupils with oral as well as written briefings. He describes how he divides each lesson into smaller tasks. Every pupil must have finished a task and confirmed his or her understanding before the lesson moves on. This way he can more easily get insight into the pupils' understanding. He describes how he needs to combine the theoretical parts with practical activities to meet up with the difficulties the pupils have in understanding specific technology content. Cesar says:

> At this school, the theoretical part disappears into the practical. It will be very much a hands-on job. If you work with materials, you have to have materials there to be able to feel and squeeze. It makes no sense to lecture on various material types and plastics and stuff. They [the theoretical and the practical] are combined more here.

The respondents stress that the learning objectives have to be clear to the pupils. For Dagny, it is important to describe the goals for every lesson. Adam and Cesar write them on hand-outs for pupils. Cesar continues:

> We spend quite a lot of time constructing pupil sheets ['lokala pedagogiska planeringar', LPP, in Swedish; literally 'local pedagogical plans']. I design a knowledge development matrix, I customise it to suit my needs, copy some from the curriculum: I rewrite them to fit the purpose. And sometimes there are some objectives that may not be within the subject of technology but that I will assess, maybe they'll have a small mini lecture on how a transistor works, and I have goals that apply to their oral presentation just because I need it so it will work in the end. One thing leads to another, if I structure my teaching well, with good presentations, structured and detailed, I know that the final result will be something that I can use … it's a type of control.

Adam observes that pupils find it difficult to connect the theoretical elements that have been taught with the practical exercises they do afterwards. An example is when they have read and talked about lattice structures and have seemingly understood what these structures are about but are unable to use that knowledge when constructing models. Adam says:

> First theories, then we turn to the practice of it. We have talked about triangular shapes, we've talked about corrugation, yet they seem to forget it all while doing the practical exercises.

Knowledge of instructional strategies for teaching technology

This component is divided into two sub-components: activities, dealing with what pupils do, and representations, dealing with what teachers say, the metaphors they use, the teaching methods they choose and so forth.

Activities

The teachers describe their teaching as being practical to varying degrees, meaning that pupils often work with hands-on tasks while the teachers assist. They talk about how *practical activities* are chosen to highlight certain aspects of the core contents and practice certain abilities. The activities in the technology classroom are predominately problem and solution-oriented. A common strategy is to start with the theoretical background, providing knowledge that is later used in hands-on activities, whereby skills and knowledge are meant to be improved. Dagny explains:

> Practical work in technology, it is mainly about solving problems. In other subjects, it may be more about making, but in technology, it is more solution-oriented.

Adam says that the practical exercises allow him to connect the goals of the curriculum; working with practical exercises helps his pupils understand the underlying theories. In his opinion, practical exercises are to a great extent about testing, building and constructing, with different materials, to visualise and present the various projects. He also claims that project work makes pupils more autonomous and encourages them to take initiative:

> Yes, it is the pupil engagement, almost all pupils find it very enjoyable, they become very involved, and especially when they have been doing their own stuff and they get that 'flow' where the teacher is almost not required; one can observe the pupils, to help them in another way. When one comes across that border, it's very fulfilling and rewarding to teach technology.

The teachers believe that practical activities always engage pupils, and even the pupils who are not too interested in the subject like to be active. Cesar says that his teaching is mainly practical. Pupils need to design and make and test their constructions. During the process, Cesar must take an active part, to help, support and guide pupils towards a better understanding of the contents of the subject.

Cesar continues to say that much of his teaching is about processes; the pupils are given a problem that needs to be solved. He usually lets pupils work in teams with equally strong members as he finds that they become more active that way. This results in increased participation in all groups. Cesar continues:

> I use structured tasks with structured information and not too much. I do not let them loose but keep the group together so that we all do the same thing. Those who finish early help those who are not yet finished.

All teachers also mention the technical development process, or design process, as an important part of the subject of technology subject. Adam stresses that structured design work, which he calls 'an industrial way of thinking' or an 'industrial mind-set', is not just part of the subject's contents. He claims that it is also a way of teaching the contents; the design process is a goal in and of itself but also an aid in gaining a general understanding of technology. Adam says:

> It is not the actual making, but you want to … it is about … according to my interpretation, it is about introducing some of the industrial mind-set – how you work, that you invent and develop, that you try to find the errors as early as possible. Then, it will be much easier to make these electronic Christmas lights work as intended.

Representations

The teachers repeatedly state that technology is about solving problems and that teaching therefore must develop problem-solving skills. Pupils can, for example, work with exercises on how to identify and analyse technological solutions based on their appropriateness and function and suggest improved design features that solve existing problems. During the work process, the pupils must be able to describe their design solutions.

Bertil explains that he asks questions to challenge the pupils more in class and asks them to find out by themselves and reconnect with earlier findings, to test materials and to find out ways to design and construct. He describes using an experimental approach with the pupils and encouraging them to try out different parts when working with mechanical equipment, such as gears and small motors.

Cesar describes how he has to include language support, even when planning his teaching. Words and concepts that emerge during the lessons are noted and given as homework. They are repeated in an upcoming lesson. He also posts words that pupils need to know in a blog about technology teaching that he keeps for the class. Cesar says:

> We have a blog in which we post, where I post 5 or 6 words and say, 'you will need to know these by Friday'. It can be anything that appears during the conversation, during the lesson, or written on the board during the lesson, and is very easy to post and check.

Cesar divides the different subject content areas into smaller sub-tasks. For each of these sub-tasks, the information needs to be clear, structured and well planned. He spends a lot of time developing clarified documents for the pupils, describing what the intended learning outcomes are and clarifying the subject matter that is addressed and assessment criteria for the specific topic. He believes that well-structured teaching, a type that keeps the group together and takes one small step at a time, provides a solid basis for assessment and improved pupil understanding. Cesar states:

> I require them to have a thought first before they start building; otherwise, it commonly turns into unstructured trial and error. To put words on the parts they are dealing with, whether it's a lever or it's about engines. It's a language that is quite advanced, I think. So we train in the meantime, both before each lesson, looking back at the lessons before and what we learned then, and after each lesson we summarise it.

Dagny describes how her pupils need to show that they can use words and concepts in connection to the topic. During the work process, the pupils have to be able to describe their suggested design solution before moving on with their work. Dagny says:

> If we take a certain theme, like building a future city, then the first goal is for the pupils to get insight into the technology that exists today with regard to sustainability and technology. Then, they come up with ideas on how to develop this technology and how they would like it to be in the future. They discuss among the group members. I want them to work solution-oriented, and innovatively.

By the teachers being active in the classroom they can scaffold and aid pupils' learning and the further development of their understanding. They use written and oral instructions and other documents that structure lessons and link activities to subject content and abilities.

Using teams with equally strong members can help pupils be more active and increase participation in group work. Working in groups enables pupils to learn together. Teaching that is thoroughly structured with well-defined milestones and sub-tasks provides increased opportunities for assessment, and more pupils will understand and keep up with the set goals.

Knowledge of assessment of technology learning

As described, in the interview guide, there were no explicit questions about the assessment of pupils' knowledge. However, discussions about assessment occurred when following up on the questions posed. The teachers describe how they assess pupils' knowledge by continuously asking questions, challenging them to develop their understanding of the subject matter. Debate and discussions, one-to-one with the pupil or in pupil groups, and observations of their work processes help the teachers to describe and evaluate ongoing activities. Adam states:

> It's about ticking every goal in the list [the core contents in the curriculum]. It's not the actual constructing but the idea behind it [that is important]; that they know how to test, modify and test again … Realising that they should have done it differently. Their reasoning and philosophising about the design process, that's what we're after.

Summative assessment, in the form of written tests, assignments and reports, is used. The purpose is often to strengthen the subject's status. The teachers express difficulties concerning how to assess group work and practical activities in a fair and reliable way. They rely heavily on experience in the grading and assessment processes. By being active and involved during the entire project and discussing assessments with colleagues, the teachers increase the validity and reliability of the process.

Summary of findings

Table 2 summarises the results. The teachers highlight different purposes for technology teaching but agree that the teaching needs to be pupil-active. All the respondents emphasise the importance of the technological development process or design process. They say that a practical-oriented teaching approach engages pupils to a great degree, but they recognise that it takes a lot of time and requires support structures in the form of oral and written instructions, as well as feedback, for learning to occur.

Discussion

In the current study, the informants were specifically asked about how they conduct their teaching, including the planning and teaching and their views on their own teaching practice. Although all categories in the PCK model are discussed below, most questions during the interviews dealt with the 'knowledge of instructional strategies' for teaching technology, which therefore also dominates the discussion. In particular, themes regarding the

Table 2 Summary of the teachers' orientations towards teaching technology

	Teaching focus	Words and concepts	Design process	Pupil participation	Practice oriented	Purpose for teaching technology
		Orientations towards teaching technology				
		Assessment				
		Pupils' understanding				
			Instructional strategies			
		Curriculum				
Adam	Goal oriented, Feedback	Important	Important	Yes	Yes	Convey a bit 'industrial mind-set', find errors as early as possible in a process because it then will be easier to get a good final product.
Bertil	Challenge pupils to try and retry Trial and error	Important	Important	Yes	Yes	Should create interest and engage pupils in the subject and also create excitement for technology.
Cesar	Increase understanding Language training	Important	Important	Yes	Yes	Pupils' knowledge and preconceptions in focus and plans his teaching on this basis.
Dagny	Interact and discuss Competitions	Important	Important	Yes	Yes	To develop problem-solving skills.

qualities and competencies of the teachers' technology teaching practices have been in focus.

The teachers in this study were well acquainted with the curriculum and subject matter and demonstrated an experience-based teaching of the subject. With a small sample of teachers one cannot discuss technology teachers' PCK in general, but the study highlights areas of specific interest for the practice of teaching technology. There are obvious similarities between the teachers' interpretations of the curriculum and preferred teaching methods that are most likely also common outside of this specific group of respondents.

Orientation of teaching technology

According to our interpretation of Magnusson et al.'s model, 'Orientations towards teaching technology' is an overarching set of attitudes towards technology and the subject of technology. By having 'knowledge of curriculum', 'knowledge of pupils' understanding' etc. as separate categories, its foundational nature can be made clear.

The respondents' ideas about the technology subject's purpose differed. Their beliefs influence their strategies for planning and conducting lessons (cf. Magnusson et al. 1999, p. 111). Using the terms from the PCK Summit (2012), these ideas arising from previous experiences are examples of amplifiers and filters. The teachers' views on the societal goals of schooling, their orientation toward preferred instructional strategies or their preferred organisation of the content of the discipline is affected by these amplifiers and filters. Therefore, teachers may approach the learning of new knowledge and its application to the classroom differently (Gess-Newsome 2015). Adam, with an M.Sc. background, expressed that technology education should convey an 'industrial mind-set'. His strategies of instruction concern learning that focuses on design processes, especially on repeated evaluations to find errors at an early stage. Bertil, who teaches crafts as well as technology, talked about how he plans his lessons to be mostly practical. His skills and subject matter knowledge mainly concern practical work. He describes himself as a doer, constructor and maker, one who encourages pupils to gain knowledge through the trial-and-error method. Neither Cesar nor Dagny described any kind of purpose or aim of the subject of technology that goes beyond what is stated in the curriculum. They pointed out how the subject of technology can collaborate with the science subjects but also how technology must be taught in another, more practical, way. The teachers in the current study have different backgrounds. Their backgrounds and beliefs are factors that characterise their planning, their choice of subject content, choice of tasks and what focus they put on the subject of technology. This, we believe, is problematic for the subject of technology because it could lead to learning development that is not equally valuable. There are strong reasons to believe that this problem is greater in technology than in others subjects as the freedom to shape the learning outcomes (Norström 2016) are greater in technology than in other subjects, where the teaching activities tend to shape the learning outcomes. As the Swedish School Inspectorate (Skolinspektionen 2014) pointed out, there is little or no consensus concerning the purpose or the contents among pupils and technology teachers. There is, however, as this study implies, consensus concerning how the subject should be taught, namely through practical activities. Thereby, the amplifiers and filters, formed by the teachers' backgrounds and previous experiences, tend to affect the outcomes of pupil learning.

As in the study by Bjurulf (2008), the respondents in the current study had different backgrounds and views of the subject's purpose. Since 2008, a new curriculum has been introduced, and the subject-specific abilities presented in this curriculum are put forward by the respondents. In the former curriculum (Skolverket 1994), the subject's contents were less clear and lacked specified skills and abilities. Interestingly, the respondents in the current study all referred to the abilities (Skolverket 2018/2011a, 2018/2011b), yet they described the purpose differently. However, the teachers in this study have experienced both curricula and therefore may have difficulty in transforming and undergoing a change.

Curriculum

In connection to what concerns curriculum knowledge, the teachers highlighted both the importance of the design process, recognised as specific to the subject of technology, and the different instructional methods that help their pupils understand the subject matter (core content from the syllabus). Practical activities are needed both to connect core contents to instructions and planning and as a means to develop pupils' understanding and general problem-solving skills. The pupils need to feel, test and try things out and make mistakes for their learning to evolve. The participants claimed this is especially important to focus on in technology education, which is also supported by earlier research (e.g. Stables 2008).

As mentioned above, the teachers use different strategies to connect classroom activities to the curriculum. Adam's starting point is the curriculum, and from there he plans his teaching and assessment. Bertil's approach is somewhat different. He starts with activities that he has previously used and found successful. These activities are interpreted to conform to parts of the curriculum. Either way, the respondents all find it difficult to have enough time to cover all the core contents.

Designing and making projects were considered important by all four respondents. Pupils' designing and making seems to be considered more important than the task of covering the whole content; therefore the teachers choose to omit part of the subject contents to allow for more designing and making. They make these adaptions quite frequently. The Swedish Educational Act (2010) states that education should be equally valuable across the entire country, which may be difficult to achieve under these circumstances. It seems as though technology teaching is fixed using certain methods and that the respondents seldom consider using other methods to enable the inclusion of the whole curriculum. Fahrman and Gumaelius (2016) found that the methods of teaching technology are not questioned but rather taken for granted, which may prevent further development of the subject.

Pupils' understanding

Understanding pupils' learning and development demands qualified subject knowledge (Magnusson et al. 1999). The respondents were all experienced technology teachers, with adequate subject knowledge. They expressed an understanding of the pupils' difficulties and how to deal with these challenges during class. The teachers showed that they adapt their teaching both to the learners and the set goals. They described how they support pupils with practical activities and with structured tasks that clarify words and concepts of importance.

Adam described how the pupils lack knowledge within certain areas and practical skills as well as propositional knowledge. When reaching seventh grade, not everybody knows what they are supposed to have learnt in the grades before. He also described the well-known problem of transferring knowledge from one cognitive domain to another, for example, how pupils know about corrugation and triangular shapes when in the classroom but are unable to use this knowledge in practice. Adam's strategy for coping with this is to adjust the level of complexity so that all pupils can follow. Unfortunately, this leads to a mode of teaching that for many pupils is not challenging enough. This is a reoccurring pattern in the subject of technology in Swedish schools (Skolinspektionen 2014). Adam claimed that not all pupils are prepared for the 'industrial mind-set' that he wants to inspire, which makes him frustrated.

Traditionally, technology has been considered a practical subject, where the focus has not been placed on reading, writing or oral communication. In the present syllabus, however, the knowledge of proper terms and concepts is stressed (Skolverket 2018/2011a, 2018/2011b). The national agency for education has also over the last decade repeatedly described the necessity of language for learning and development (e.g. the project 'Läslyftet' [Boost for Reading] since 2015). Among the four respondents, Cesar spoke extensively about the need for language skills for learning technology, maybe because his pupils to a large extent are second language learners. For him, it is clearly apparent that adequate language is required for proper learning and understanding, even in technology.

Instructional strategies

The respondents described how they plan their teaching, starting with the core contents in the technology syllabus, the pupils' current understanding and the abilities they are to develop. The instructional structures the teachers use depend on their pupils' needs. They partake in supporting conversations, promoting discussion and frequently checking pupils' understanding and whether they are grasping the relevant terminology. They use oral and written instructions and pupil documents to link activities to the core content and abilities. Supporting learning by checking knowledge of words and concepts are established strategies also found by other researchers (Kimbell and Stables 2007).

Practical activities

The respondents chose practical activities such as material testing, model construction and applications of design-based learning—trying and retrying, evaluating and changing models, construction or solutions with pupils, including the evaluation of their own work processes.

Practical activities, or hands-on activities, are important methods in technology education; they are important as content in themselves but also to gain a deeper understanding of other aspects of technology. Teachers must be aware of the practical activities' dual nature—as content and means—when planning, evaluating and assessing teaching (cf. Stables 2008; Kimbell and Stables 2007). A prerequisite for establishing knowledge practices around hands-on activities that support pupils' learning is that teachers have knowledge about subject-specific knowledge cultures and can put that understanding into practice in the classroom (Carlgren 2015). According to the respondents, the knowledge culture of technology and technology education demand a teaching practice that is different from other subjects. When working with practical activities in the technology classroom, technology teachers describe how they need to teach differently because of the problem-solving-oriented contents (Fahrman et al. 2017). Therefore, hands-on activities, with their particular knowledge culture, need to be further discussed, and their use in technology education needs to be further developed to increase pupils' learning and make the subject contents visible and graspable. This would provide increased opportunities to avoid 'non-reflective making', as described by the Swedish School Inspectorate (Skolinspektionen 2014).

Another challenge with all kinds of practical activities is that they take up much of the allocated time while also being taken for granted; the use of practical work as a method of teaching is not being questioned. At least Bertil, Cesar and Dagny all described how they skip parts of the core contents to fit the time schedule. They do not, however, reflect on whether they could use other means of teaching that could allow pupils to reach the learning objectives quicker. Practical activities are seen as the obvious way of teaching technology.

Kimbell and Stables (2007) emphasised that a careful, self-conscious, structured teaching method, such as the design process, is helpful in increasing pupils' learning. Activities in technology are commonly centred on designing and making (Norström 2016). When building and constructing, the interviewees noted that pupils develop problem-solving abilities and learn how to work with the product development process. They stressed that this is especially important to focus on in technology education as pupils thereby develop knowledge of a process in which they design, test, evaluate and redesign their prototype or project. Notable is that none of the respondents referred to transfer effects, that is, that knowledge about this process could be useful in other contexts; but claim that it is intrinsically important to understand in the subject of technology.

Classroom communication

Fox-Turnbull (2010) discussed the impact of supportive talks in technology education and suggested that by understanding the full impact of classroom conversation and facilitating its use in the classroom, teachers can greatly enhance learning in technology education. Conversation with and between pupils can give teachers insight into the impacts of previous and specifically targeted learning experiences on learning in technology. Classroom dialogue can also enhance the understanding of how learning occurs in technology and how interactions with pupils and teachers advances thinking about technological concepts and practice. Kimbell et al. (1991) and Kimbell (2012) stated that dialogue lies at the centre of the learning process. Stables et al. (2016) explored using a dialogic framework of questions as a method for developing pupils' learning. According to their findings, the dialogue is critical when exploring and developing thinking and ideas around design projects.

The teachers in the current study had all come to conclusions that are in line with those of the researchers mentioned above; the teachers stressed the importance of the ongoing communication they have with their pupils during all practical activities. They do not let the pupils work by themselves; instead, the teachers interfere, lead or scaffold and discuss with them. The teaching is planned and divided into small sections of subject content to maintain a common understanding and keep pupil groups working together efficiently.

Assessment

Questions about assessment were not the focus of the interviews, but one can note that the teachers talked of planning and conducting their teaching in ways so that they will be able to assess correctly and fairly. They mentioned their experience and background as key factors in this regard.

For the teachers, knowledge of assessment for the subject of technology means to continuously assess the pupils during classroom activities. Discussions, one-to-one with a pupil or with a pupil group, oral feedback and observations of ongoing activities are the main means for assessment among the four respondents. Adam, Cesar and Dagny all rely on meticulous documentation of pupils' achievements. Adam and Dagny use documents to clarify what the learning objectives are and how the pupils will be assessed. The documents are created at the start of each new theme. Cesar uses his pupil sheets in everyday communication with pupils and for planning each lesson. His documents are continuously revised depending on how the teaching turns out and if the objectives need to be revised. This is one of several methods that he has developed to cope with his group of pupils, where both subject knowledge and skills in the Swedish language vary considerably. Bertil's means of assessment is based on his 'gut feeling' or tacit knowledge, developed through his long teaching career. Bertil's method allows for greater flexibility but is also less transparent. The levels of the grading system are to some extent open to interpretation, which also means that the lowest acceptable level easily becomes unclear. The detailed documents used by Adam, Cesar and Dagny not only allow them to grade pupils fairly but also to tell which pupils have failed to meet the minimum requirements.

The teachers expressed different views about pupils working in groups. Collaboration is considered an important aspect of project work, but it makes fair assessment of individual pupils difficult. Adam, for this reason, chooses to avoid group activities whenever possible. The others use individual assignments in addition to the group work to enable individual assessment. They also referred to their experience as a technology teachers, which enables them to informally assess pupils' knowledge while observing them and partaking in their work.

Dagny described how she works together with colleagues to establish fair and equal criteria for assessment. Adam and his colleagues do this too but not with the same regularity. Neither Cesar nor Bertil mentioned anything like this. In Bertil's case, one major reason is that he works in a small school where he is the only technology teacher. This is the case in many schools, and most likely, it is an important contributor to the inequality in the subject contents taught, levels of difficulty and assessment in the subject of technology (as described by Skolinspektionen 2014). Both Norström (2014) and Skogh (2006) described how the lack of consensus regarding content and practice could result in insecure teaching and unclear criteria for assessment.

Conclusions

The purpose of the present study has been to gain insight into the considerations of experienced technology teachers and how they describe their expertise and teaching practice, which were analysed in relation to PCK. The respondents had all taught technology in lower secondary school for several years. By exploring experienced teachers' practice, this study illustrates how they view the subject of technology, how they apply their experiences and how they transform these experiences into teaching practice.

In Sweden, a common view is that the subject of technology has weak traditions (Skolinspektionen 2014; Teknikföretagen and Cetis 2012). The current study indicates that this is partly true. Speaking in PCK terms, the purpose and teaching focus of the respondents within the category 'Orientations towards teaching technology' vary considerably. However, when it comes to 'instructional strategies', the consensus is striking. It seems as though the subject of technology in this area has quite a strong tradition, one mainly of methods and strategies for teaching. The subject of technology is in practice defined by its classroom activities rather than its purpose or intended learning outcomes. In the curriculum (Skolverket 2018/2011a, 2018/2011b), technology is defined through its purpose, abilities and core contents. In practice, the respondents define this subject mainly by project work in which the pupils are to develop the abilities. The core contents may be reduced if there is a lack of time. To choose another, less time-consuming, teaching strategy is seldom considered.

Technical development processes, or design processes, are part of the core contents of the subject of technology. By focusing on project work, these processes become central parts of the technology education. According to the respondents, this is appreciated by the pupils and is also rewarding for the teachers. This method of instruction provides pupils with ample opportunities for collaborative learning. It also enables teachers to structure and direct pupils' work through instruction and feedback, which is positive for their development (Fahrman and Gumaelius 2016).

According to the respondents, the main drawback of the chosen 'instructional strategies' is that teaching based on technical development processes tends to be very time-consuming. It is also difficult to assess pupils' learning, especially if the work is carried out in groups. Apart from these, there can also be major problems concerning equality. When teachers remove parts of the core contents that they cannot fit into the limited time frame means that the subject contents will differ between schools and classrooms.

The Swedish School Inspectorate (Skolinspektionen 2014) suggested that more technology teachers with proper training are necessary for the subject's development. However, the results of this study show that a greater number of teachers is not enough. For the subject of technology to develop further, a broad discussion concerning how to create a consensus in regards to its purpose and contents should take place. Important questions include how the subject could be clarified and made more relevant while taking both the curriculum and the present teachers' experiences into consideration. The good examples and fruitful teaching strategies that do exist must not be lost during the improvement process.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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