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Design, system, value: The role of problem-solving and critical thinking capabilities in technology education, as perceived by teachers

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Abstract

The Organisation for Economic Co-operation and Development (OECD, 2013) defines its views on necessary skills for 21st century citizenship and life-long learning, advocating a generic skillset of literacy, numeracy, and problem-solving in technology-rich environments. Other sources also include critical thinking as a vital 21st Century skill. There are also those who question the concept of 21st Century skills, claiming that, although very important, these skills are in fact old and have been around for decades, or even centuries. Therefore, in many countries, skills such as critical thinking and problem-solving are already addressed in technology education as part of the core subject matter, especially regarding competencies connected to technological literacy. Critical thinking and particularly problem-solving have been well researched in technology education, but seldom from the teacher's point of view.

The aim of this article is to investigate Swedish compulsory school technology teachers' views on problem-solving and critical thinking as curriculum components and as skills addressed in teaching. Twenty-one teachers were subjected to in-depth qualitative interviews. The findings of the study show that the interviewed teachers can be said to express three approaches to teaching about technology in a critical thinking and problem-solving mode: (1) the design approach, (2) the systems approach, and (3) the values approach. Even though the present Swedish technology curriculum does not explicitly mention these skills, the teachers say they incorporate critical thinking and problem-solving in different settings within the subject of technology. Problem-solving and critical thinking are not seen as generic capabilities but they are always connected to, and integrated with, subject content in technology by the teachers. The teachers mix the approaches depending on the teaching content, especially when teaching about complex technology, although there is a tendency to disregard critical thinking capabilities when dealing with design, and neglect problem-solving skills when addressing values.

Key words

problem-solving; critical thinking; technology education; 21st century skills; design; system; value; technology teachers; Sweden

Introduction

The Organisation for Economic Co-operation and Development (OECD, 2013) defines its views on necessary skills for 21st Century citizenship and life-long learning, advocating a generic skillset of literacy, numeracy, and problem-solving in technology-rich environments. Other sources also include critical thinking as a vital 21st Century skill (Binkley et al., 2012). There are also those who question the concept of 21st Century skills, claiming that, although very important, these skills are in fact old and have been around for decades, or even centuries (see, for example, Kirschner, 2015).

In many countries, therefore, these skills are already addressed in technology education as a part of the core subject matter, especially regarding competencies connected to technological literacy (Avsec & Jamsek, 2016; Jones, Buntting & de Vries, 2013; Pearson, 2007; Pearson & Young, 2002). Although hidden under different labels, 21st Century skills have been part of the Swedish technology curriculum for the compulsory school for the past decades as core capabilities such as critical thinking and problem-solving. The current Swedish curriculum for the subject of technology focuses on identifying problems and finding technological solutions to these problems, as well as critical analysis of modern technology usage and its everyday interaction with people and society (Skolverket, 2016). The curriculum is also in line with research in the philosophy of technology, where problem-solving and critical thinking are seen as central to technology activities (e.g. Mitcham, 1994; Ropohl, 1997).

Problem-solving is consequently an essential feature of technology education. Indeed, it can be said to be part of almost any technology learning activity in primary and secondary classrooms around the world. Therefore, the research in this area of technology education is substantial, from the origins of the field in the early 1990s and onward. During the 1990s, McCormick and his team investigated the nature of the problem-solving activities that students engage in during "design and make" projects in design and technology (D&T) classrooms in the UK. One important finding was that students need a varied set of approaches at different stages in the design process (Hennessy & Murphy, 1999; McCormick, 1995; McCormick, Murphy, & Hennessy, 1994). Hill explored design and technological problem-solving in real-life contexts in some projects in Canadian primary and secondary schools (Hill, 1998), and concluded that these design processes were dynamic and creative, and students could put technology in a societal and environmental context. In a Finish study, Lavonen *et al.* studied problem-solving in a teaching experiment where eighth-grade students used programming tools in a control technology project (Lavonen, Meisalo, & Lattu, 2002), and found that the majority of learning processes were collaborative. Mioduser & Kipperman investigated specifically the evaluation/modification phase of a design and problem-solving project in an Israeli grade seven class, something which resulted in a more general conception of students' mental models of problem-solving (Mioduser, 2009; Mioduser & Kipperman, 2002).

In a cross-European project, Hamilton studied primary students working in three groups to develop a solution to a design and technology challenge that originated from within a story context. Teachers intervened to varying degrees in each of the groups, from being largely passive in the first group to being very active in the last, with the latter positively impacting on collaboration, productivity and learning outcomes (Hamilton, 2007). Barak & Zadok and Barak & Assal investigated learning and the problem-solving process among Israeli junior high school students participating in robotics projects; some students were found to be inventive but there were also those who only carried out the most basic tasks (Barak & Assal, 2016; Barak & Zadok, 2009). Castledine & Chalmers similarly explored what problem-solving strategies Australian primary students employed when working with LEGO robotics, and whether they were able to relate their problem-solving to real-world contexts in an effective way. The researchers concluded that the students were generally able to relate to the real world, and that the robotics activities helped them with this (Castledine & Chalmers, 2011). Middleton studied how students could learn about sustainability in technology education in Australia, and, further, the relevance of problem-solving in this learning. He concluded that the problem-solving approach provides many opportunities to students engaging with ideas of sustainability (Middleton, 2009). Hérold & Ginestié explored in a French context how to make problem-solving in project work in technology teaching more effective, and concluded that this can be achieved by analysing the student's level of understanding of the activity and offering appropriate support (Hérold & Ginestié, 2011).

Critical thinking is also a crucial component of technology education, especially as it is a central skill in problem-solving, but it is nevertheless under-researched and the little research that exists is of later origin. Wells discussed the place of creativity, imagination and critical thinking when designing, and concluded that design and problem-solving cannot be confined to a limited set of prescribed steps (Wells, 2013). Yu *et al*. studied how Taiwanese senior high school students apply conceptual knowledge in order to think critically when learning the history of communications technology. The researchers found that although the students displayed various misconceptions, for example, concerning systems knowledge, students' critical thinking positively correlated with their application of conceptual knowledge (Yu, Lin, & Fan, 2015).

Although primarily focusing on students' work, the great majority of the above studies on problem-solving still point to the importance of what the teacher does by way of instruction and support for successful outcomes of problem-solving activities, regardless of the degree of "student-centredness". How the teacher deals with critical thinking and supports students in acquiring this skill is also considered as very important in the studies on critical thinking. Therefore, it is somewhat surprising that very few studies focus on the teacher and his/her views on problem-solving and critical thinking. Exceptions are DeLuca who studied "best practice" of problem-solving in American schools through a survey about problem-solving activities that teachers thought they had successfully implemented. The findings indicate that technology teachers use teaching methods that promote valuable problem-solving skills, but that they need to ensure that a wider spectrum of appropriate processes and thinking skills are taught (DeLuca, 1991). Mettas & Constantinou explored the influence of working with primary school children in Cyprus on a technology fair on the educational value and meaning attached to problem-solving skills by pre-service primary teachers. The results indicate that the technology fair contributes to improving pre-service teachers' understanding and application of problem-solving strategies within the technology domain (Mettas & Constantinou, 2007). There is still a gap in the literature concerning teachers' views on problem-solving and critical thinking in technology education.

The aim of this article is therefore to investigate Swedish compulsory school technology teachers' views on problem-solving and critical thinking as curriculum components and as skills addressed in teaching.

Theory and Methodology

For this article, the authors analysed interviews with twenty-one compulsory school technology teachers (for students aged 7-16 years old), using a qualitative, semi-structured interview guide (Kvale & Brinkmann, 2014). Each interview was conducted at the informant's workplace, and varied between forty-five and ninety minutes in duration. The interviews focused on exploring the teachers' views on their own teaching within the subject of technology, with follow-up questions regarding specific teaching activities and subject content that the teachers mentioned during the interviews. Problem-solving and critical thinking capabilities were not addressed *per se* during the interviews, but were construed by the authors during the initial steps of the analysis.

In the analysis, we emphasise the teachers' collective experience and views of technology education, and we consider the data as a collective space of meanings. In a sense, this way of looking at the empirical material has certain similarities with phenomenographical analysis, particularly the concept of *outcome space* (Marton, 2014). Thus, the findings primarily reflect the collective breadth of experiences, although in the conclusion we also address the relationship between collective and individual experiences regarding problem-solving and critical thinking.

In accordance with ethical guidelines presented by the Swedish Research Council the respondents were presented with the purpose of the study and told that their participation would be completely voluntary. They were also told that the interviews would be de-identified in regard to names and geographical origin, and that the collected data would be stored safely and would not be used outside the research context.

A dataset was chosen from the interviews containing the teachers' own viewpoints on their teaching about technology when employing aspects of problem-solving and critical thinking. The dataset was then organised and coded using the software MAXQDA. The analysis followed an interpretive process to derive themes from the dataset. By doing so, the authors employed an analytical model based on the hermeneutical spiral and a six-step process of thematic analysis (Braun & Clarke, 2006; Robson, 2002). The authors' combined background experience in teaching technology was used to provide the necessary analytical horizon for the interpretative analysis.

The first step of the thematic analysis was to transcribe the interviews. The authors employed the interpretive process of the hermeneutical spiral by repeatedly reading the material (Robson, 2002). The second step of the process involved an initial coding of interview transcripts using the software MAXQDA. Excerpts of texts were coded using an interpretive approach. Whenever the informants expressed views about their teaching practice that could be explicitly or implicitly related to problem-solving and/or critical thinking, the excerpts were coded with a descriptive code label. The definitions of problem-solving and critical thinking that guided this step of the thematic analysis were based on the literature review above.

The third step continued with a multitude of derived codes that underwent a sorting process to order them into a tree-structured hierarchy. Three themes were constructed by merging codes that were near to or overlapped each other. The fourth step required the themes to be reviewed, revised and refined to minimise the overlap between the themes. The highlighted themes for the technology teachers' narratives were later discussed, confirmed and thereby validated among peers within technology education research.

The fifth step commenced with the definition and naming of the three key themes, bringing out the essence of each theme and the aspects of the data they covered. The themes were: (1) The design approach (design and construction of technology), (2) The systems approach (the complex and networking structure of technology), (3) The values approach (the social and technological implications of technology, for the individual, society and environment). Each theme also contained five underlying sub-themes. The sixth step involved presenting exemplary data of each theme as part of this study's results from the thematic analysis.

Illustrative quotes were also translated into English and abridged by the authors in order to increase readability.

Regarding validity, the teachers were not asked directly about problem-solving and critical thinking but were asked rather more general questions about their views of their teaching. Thus, we gave the teachers freedom and space for their own answers, but we also, in a sense, had to construe an analytical narrative on problem-solving and critical thinking with certain themes. Analysis of the data was also peer-reviewed at a research seminar in order to check the validity of the themes. Strictly speaking, our results can only be seen as representative of the twenty one interviewed teachers, but the sample was fairly large and the findings can therefore generate intersubjective understanding of the technology teachers' views. The results of this study therefore point to possible ways that teachers do and can approach problem-solving and critical thinking in technology classrooms, in Swedish and international contexts (Cutcliffe & McKenna, 1999).

Findings

When treated as a collective outcome, the analysis of the teachers' views resulted in three themes of teaching approaches that promote critical thinking and problem-solving skills. The first theme centred on a design approach, focusing on the design and construction of technology. The second theme revolved around a systems approach, concentrating on the complex and networking structure of technology. The main focus of the third theme was the values approach, converging on the social and other implications of technology. Each theme also provided several sub-themes that together defined the specific theme.

The design approach

Most of the interviewed teachers said that in the problem-solving process the production of ideas through creative acts was one of the core capabilities that the students had to learn and develop. Diana explained that the capacity to draw and illustrate an idea was an important step in the design process when constructing a physical model. Alexander mentioned that to construct a physical model or a working prototype includes several stages in the construction process. "To fail and to redo, improve", as Alexander expressed it. One of these steps may include an iterative loop, i.e. returning to revise the drawing or even the idea of the construction if the students find potential for improvement. Felicity extended this approach when she saw a multitude of knowledge areas emerging while working with the design aspects of creating technological artefacts:

> *Then there was this assignment with movement and construction. It was wonderful because we could include technical drawing with drafting and forces […]. The students could observe, for example, that when they added weight their constructed vehicles couldn't tolerate the stress they were subjected to. Then they had to redo their constructions, improve them and so on. (Felicity)*

Isabelle saw great potential in promoting idea creation while working with problem-solving and technological solutions as the students should be able to find solutions when presented with problems in their everyday life:

> *Creativity, not to lose the urge to be curious. The students need to think about everyday solutions from their everyday lives, that is, "Oh, now we have this sort of problem, how can we solve this?" The student*

should not be just provided with solutions or given instructions to "do this". The student should dare him or herself to come up with ideas. (Isabelle)

Furthermore, the interviewed teachers also saw the activity of presentation as a vital step in the design process, as the students present the outcome of the whole problem-solving process to other students – mainly to show that they have managed to fulfil the class assignment but also to receive recognition for their creativity.

Theme	**Items**	**Description**
The design approach (design and construction of technology)	Creativity and idea generation Drawing and illustration Construction Iterative work methods Presentation	The ability to design and construct technological artefacts through a number of activities; (a) By generating ideas from understanding technological or societal needs or problems, and to use these as a basis for a technological solution. (b) By drawing a conceptual representation of the suggested solution. (c) By constructing a conceptual or working model/prototype for the derived solution. (d) By continuously revising the design activities if there is room for improvement in the design process. (e) By presenting the solution: for example, in the classroom as part of an assignment

Table 1 The design approach

The systems approach

Being able to understand the technical processes as well as how different technological solutions can interact with each other was a core problem-solving element when teaching about complex technology such as technological systems. The importance of understanding how the parts of a system integrate to a whole is something that Leonard focused on in his teaching. He exemplified this in his interview when he talked about the computer as an analogy for a technological system. One essential aspect of understanding is seeing how the computer power supply is distributed within the system. He and other teachers used examples of smaller electricity-dependent technological systems and how they were related to larger electricity distribution systems. In his teaching, the interfacing aspects of systems provided areas for investigation, especially for students using their problem-solving skills to identify possible disruptions of service within a system or in relation to another technological system.

Charlie strove to promote a systems approach when discussing with his students how large technological systems like municipal water and sewage systems coped with distributing both fresh water and wastewater to and from the connected households:

I believe that it is all about making the student grasp the concept of [...] how [technology] is connected and things function out there in society. I mean, these [large technological municipal systems] for garbage and water - how do they actually work? How does [the fresh water] get from the lake to the households' faucets? And the garbage, what happens to it? I think that [the students] should have this knowledge, because then - well - it makes it easier for the students to engage in recycling if they, quite frankly, know what happens. (Charlie)

Nelson also used the computer as a kind of system model, and focused on the need to know the interchanging flows of information between the computer user and the computer itself in order to problem-solve in a digital setting. The human-machine interface provided several important opportunities for critical thinking, which was something that he further elaborated upon when he talked about a system's outputs and the effects on individuals, society, and the environment.

The interchanging processes between different components within a system were something that Kate also focused on in her teaching. Peter extended this to include also an opening of the "black-box", i.e. the outer exterior of a system. By doing so, the interior of the system becomes accessible to the student for the purpose of critically evaluating the importance of individual components and how they affect the system's processes, and in particular the outputs of the system.

George explained further in his interview that knowledge about how complex technology interconnects provides the student with tools for navigating a technology-enriched world. The student will thus be able to perform simple, yet essential, problem-solving tasks when dealing with certain parts of a technological system:

The students should understand how things work and how to use tools, as they are expected to manage themselves when school is finished. The students should be able to change a plug, understand why it is a plug and why they should not replace the plug with a nail to get the electricity working again in the household. They need to understand cause and effect. They need to understand the world around them and they need to acquire the skills to be able to influence it. This could mean to understand an electrical system, and to be able to use it in a sensible way.

Theme	**Items**	**Description**
The systems approach (the complex and networking structure of technology)	• Black-box • Micro-macro • System interfaces (input/output) • Networking parts and components • Processes	The capability to understand and critically evaluate technological systems from a number of viewpoints based on identifying key elements of the system: (a) By observing the physical structure of complex technology, such as technological systems, through opening up the black-box that encompasses the system in order to critically investigate the internal structure of the system. (b) By observing a technological solution or a system through its different parts and its whole structure so that the

		overall functionality is observable. (c) By identifying and observing the interfacing components of a technological system to determine how the system interacts with its surroundings, i.e. what enters the system by its input(s) and what exits the system by its output(s). (d) By observing and identifying the networking parts and components within a technological system. (e) By identifying and observing a system's processes and the impacts on the system's functions that (changing) different components can have

Table 2 The systems approach

The values approach

Understanding technological change was something that the teachers found to be a core ability when critically analysing and evaluating technology. The temporal understanding of a technical solution, i.e. historical background, present-day status, and the possible future development, was considered especially important. Peter made a point of this in his teaching, where the students, after understanding the reason behind a technological solution, also continued to challenge their own thoughts about technological development. Quentin found it necessary for the students to be able to discuss implications for society, environment and individuals. This was something that other teachers in this study exemplified with technological malfunctions, such as problems in filtering in a sewage plant or the failure of a fuse in a domestic setting.

The social aspects of ethics and moral values were also important for critical thinking capabilities, according to the teachers. Kate introduced this in her teaching by discussing fairness with her students, for example, asking whether every human has the right to drink filtered, clean water. Ursula took it further by making the students question the need for cheap clothing if child labourers manufacture it. Some of the teachers found these kinds of discussions relevant when comparing and evaluating different sorts of technological solutions. In Alexander's and Oscar's teaching, qualitative comparisons of various technological innovations such as bridges, household appliances, and digital technology were things that they focused on. Nelson explained in his interview that the students should be able to question what is important regarding technological development – and for whom. The students should be able to question whether certain technological solutions should even "exist" in regard to personal integrity:

> *I believe that it is really important that the researchers and technicians in the future know how to answer the question of "Who or what is going to be in charge?". Will it be just the money or will it be...? Well of course money will be an issue in the future, but at what cost? It is really important that you are aware of such things and able to participate in a discussion about such things in school. We [the teachers] help to make students think and reason about such issues. I believe that it will be even more important to do so in the future. For example, I'm thinking about the technology behind 'transponders', that it is possible to*

> *track every single human and their position. Do we want to have [a society] like that? How can [technology] be abused and so on? (Nelson)*

Ursula strove to empower her students when teaching about the consequences of technological development, and tried to show them that they as individuals possessed the ability to influence industries to rethink their business strategies when they as consumers placed certain demands on the product they wanted to purchase:

> *Today I can say that I want a car that is better for the environment, that needs to consume less fuel. That's what I want, and that's what I want to buy. Then I am able to influence as a consumer the entire automotive industry. (Ursula)*

Additionally, the teachers in this study also included problem-solving discussions about efficiency when comparing different solutions. However, regardless of the characteristics of a technological solution, the teachers also mentioned the importance of recognising the human agent in technology, as Oscar explained in his interview. He further developed this thought by saying that humans are the catalyst for technological change as humans define needs and act on them to develop solutions.

Theme	**Items**	**Description**
The values approach (the social and technological implications of technology, on the individual, society and environment)	• Then-now-future • Implications for the individual, society and the environment • Ethics and values • Comparison and valuing of results • The human agent	The ability to analyse and evaluate technology through a set of inquiring activities; (a) By acquiring a temporal understanding of the technological solution's development throughout history and in the future. (b) By identifying the solution's implications on the individual, society and environment. (c) By a value-based questioning of the solution from a moral and ethical viewpoint. (d) By comparing and evaluating different solutions, as well as the results of each solution. (e) By identifying and explaining the role of humans as agents and developers of technology

Table 3 The values approach

Discussion

In this study, the authors examined how technology teachers within the Swedish compulsory school perceived their teaching when including critical thinking and problem-solving capabilities. The analysis shows that the interviewed teachers used different types of technological contexts, in particular through three approaches; (1) the design approach, (2) the systems approach, and (3) the values approach. An interesting note is that these approaches were mixed by most of the interviewed teachers when teaching about particular areas of technology. For example, Kate used two of the approaches when she used the local sewage plant as a teaching object and discussed the plant from both a system (focusing on the system's structure and function) and value (primarily the system's implications) perspective.

The design approach

Understanding and design of artefacts take up a considerable part of the overall teaching about technology in Sweden (Bjurulf, 2008) as well as in other countries (de Vries, 2005; DeLuca, 1991; Jones, Buntting & de Vries, 2013). This way of teaching harmonises well with being technologically literate, i.e. being able to understand that technological solutions originate from the designer's ability to identify and transform needs into ideas and after that into concrete artefacts (Ingerman & Collier-Reed, 2011; Wells, 2013), which also corresponds with the informants' self-confessed desire to teach students creative methods for idea generation. The design process adds more value to the expected results if the designer continuously evaluates the working methods and usage of materials when constructing physical models or artefacts (Jones, 1997). As such, being able to communicate ideas and concepts through various models is a vital part of being technologically literate (Compton, 2013; McCormick, 2006). The teachers saw other beneficial effects such as critical thinking skills, problem-solving capability, personal growth and collegial acceptance when the students were able to display their ability to produce something from a design process. The fact that the design process is not linear but involves going back and forth and redoing certain stages was hinted at by the teachers (cf. Williams, 2000), which meant that the structure of the teaching had to be quite student-centred. Similar views were expressed by the pre-service teachers in the Cypriot study, because they had to introduce more constructivist and progressive teaching methods in order to get the design project with the children to work (Mettas & Constantinou, 2007). The present Swedish curriculum for the compulsory school provides details on the design process that corresponds quite well with the interviewed teachers' ideas about how they teach (Skolverket, 2016).

The systems approach

To be able to grasp, critique and solve problems related to complex technology requires a system understanding (Hallström & Klasander, 2017; Ingelstam, 2002; Klasander, 2010; Koski & de Vries, 2013; Williams, 2000; Yu et al., 2015). It was evident from the teacher interviews that the enormous physical size of some systems, such as national electricity distributions systems, hindered students from achieving a clear view of the system's internal structure. Nelson used the black-box model of systems (input, process, output) when teaching about how the systems' interfacing components could relate to individual(s), society and the environment. Understanding the internal functionality of the system requires comprehension of the parts of the system, i.e. the components and sub-systems and their connectivity through different processes (Lind, 2001; Svensson, 2011). This is something that Oscar said he promotes in his teaching by using a micro-macro transition when observing a system. Leonard mentioned that by observing the interconnectivity of systems and sub-systems, the students are able to use their problem-solving skills to identify potential disruptions in connectivity and their consequences. However, when viewing the technology curriculum, the guidelines do not explicitly define what aspects of system understanding the students need to learn. For example, the curriculum does not mention the concepts of input, process and output, which are commonly used in the discussion of technological systems and critical thinking about them (Klasander, 2010; Martin, 1990; Svensson, 2011; Tamir & de Vries, 1997).

The values approach

For students to develop problem-solving and critical thinking skills and thereby achieve a broader understanding of how technology, individual(s), society and the environment relate to each other, they also need an understanding of how to value technology (Keirl, 2006; Stables & Keirl, 2015). Ethics are in the foreground when the teachers present discourses about the consequences of technological choices. Ursula conveys these concerns in her teaching, especially the social impacts of buying cheap clothes from developing countries, and she discusses the consequences for the environment as well as for other individuals. Her main point is that her students need to reflect on how the clothes are manufactured. Ursula thus shows an awareness of the breadth of sustainability as a concept, which in most present-day definitions includes not only environmental but also social and economic aspects. In technology education, there has traditionally been an emphasis on economic issues through a product development culture (cf. Elshof, 2006), but, according to Stables, a more integrated, critical view is needed to fully encompass environmental, economic, social and ethical aspects of sustainability (Stables, 2015). An integral part of teaching about values is also to produce a critical analysis of both human and automation aspects of controlling technology, as Oscar emphasised in his interview (cf. Carr, 2015).

Evaluating technology is a central part of the subject of technology in the curriculum, as consequences of technological choices and adaptation of technology for humans are mentioned in the curriculum. Technological change and implications for individuals, society and the environment are also areas that are firmly established in the curriculum, something which is reflected in the teacher interviews (Skolverket, 2016). The analysis shows that the teachers' ideas about their teaching align with the curriculum in this respect, although the curriculum does not give any detailed guidelines about how to teach or assess these areas.

Conclusion

In conclusion, this study shows that the teachers said they taught about specific technological artefacts and systems, and utilised different approaches at the same time, depending on what was in focus at any given time in their teaching. For example, teaching about certain technological systems such as a sewage plant could involve two of this study's approaches – system and value. This example illustrates the multi-faceted character of teaching about technology and that these approaches are not used exclusively and separated from each other, but rather that the teachers integrate two or all approaches to establish a nuanced learning environment. This is interesting bearing in mind the dominance in particular in the Anglo-Saxon world of problem-solving as design (Barlex & Trebell, 2008). However, this finding also contrasts with the results of a study made by the Swedish Schools Inspectorate that Swedish technology teachers engage a great deal in "design and make" activities without contextual components (Skolinspektionen, 2014). This integrative pedagogy on the part of the teachers is therefore a key finding in this study, and also, in fact, an important pedagogical consideration; a teacher could teach any topic and depending on the approach, students could experience a very different set of expectations concerning critical thinking and problem-solving.

Despite the integrative pedagogy, however, our findings also show a progression of the approaches that might be problematic from a technological literacy point of view. The element of problem-solving is great in the design approach, a little less so in the systems approach, and not prominent at all in the values approach. Critical thinking, in contrast, is not so clear in the design approach but a little more so in the systems approach, and it is very salient in the values approach (see Figure 1). Even though the teachers seem to mix the approaches, it is thus also clear that design lacks an element of critique and that values are not connected so much to problem-solving but rather to broader societal issues, at least as the teachers talked about them (cf. Wells, 2013). This imbalance might be due to teachers' inexperience of addressing problem-solving and critical thinking due to them being implicit in the curriculum, but it may also be, for example, that values have not traditionally been integrated with problem-solving components in technology education. Further research is needed to investigate this.

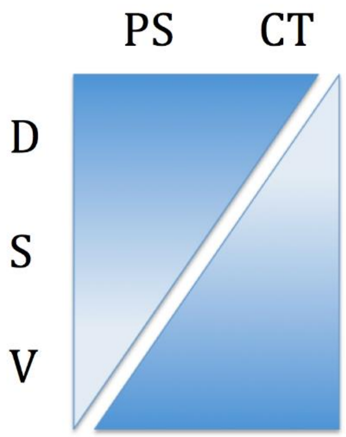

Figure 1. The relationship between elements of problem-solving and critical thinking in the three approaches (D = design; S = system; V = value; PS = problem-solving; CT = critical thinking).

When the teachers in our study said they incorporate critical thinking and problem-solving capabilities as well as other skills like creativity in technology education, they were also contributing to the teaching of 21st Century skills. However, our results show that 21st Century skills are not only seen as generic capabilities but they are always connected to and integrated with subject content in technology by the teachers; it is problem-solving of and critical thinking about *something*, not just a generic capability.

Implications and future research

This study has shown that according to Swedish technology teachers, different approaches can be employed when teaching about technology; the design, the systems, and the values approaches to technology. These approaches can be seen as an interpretation of the 21st Century skills of critical thinking and problem-solving in a technological context. As such, these approaches can be used by teachers when planning teaching in technology as well as by authors designing textbooks and other teaching material in technology education, when the intention is to promote problem-solving and critical thinking together. However, based on the results of this study, for successful implementation of the three approaches it is necessary to pay particular attention to incorporating critical thinking skills when dealing with design and systems, and problem-solving capabilities when dealing with values.

Future studies should explore further how these approaches can be used together with scaffolding techniques to improve primary and secondary students' conceptual understanding of technology in areas such as digital technology and ICT, innovation and sustainable development (cf. Middleton, 2009). The approaches can possibly form the basis for a concrete teaching design that progresses according to the age of the students.

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