Developing student teachers' PCK for teaching technology with a sustainability edge in primary school

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ABSTRACT

In Swedish primary schools, technology teaching may appear different depending on what educational setting the pupils meet. Many pupils experience the subject of technology as taking part in practical making-activities without recognizing the technological knowledge involved, and many teachers feel uncertain of what and how to teach technology, especially concerning sustainability. Thus, it is necessary to pinpoint these issues within teacher education. This paper presents the first iteration of a Design-Based Implementation Research (DBIR) study on a teaching module that provides student teachers with theoretical and practical knowledge in technology education. The purpose of the study is to capture and understand how student teachers transform acquired knowledge and skills into Pedagogical Content Knowledge (PCK) for teaching technology in primary school. Special attention is on how student teachers evolve relations between technology education and sustainable development. The study is designed and implemented in line with DBIR based on principles of collaboration and has strong connections between practice and theory (Fishman & Penuel, 2018). The participating researchers, also the teacher educators, have together with teachers at a municipal technological resource facility jointly identified underlying premises such as policy document statements; topics and content of value for all participants; potential participating schools; and reviews of previous research. The study includes 12 student teachers enrolled in a science and technology course. Data is collected in several steps including student teachers' written individual reflections, their project assignments, their lesson plans, and focus group interviews. Based on qualitative content analysis, components of PCK are traced to elucidate the transformation of student teachers' PCK for teaching technology with a sustainability edge. The results contribute to knowledge of what efforts, such as teaching module design features and connections to sustainability, should be made to develop student teachers' PCK for teaching technology in primary school.

Key Words: Design-Based Implementation Research, Pedagogical Content Knowledge, Sustainable-Development, Teacher Education, Technology Education

1. INTRODUCTION

Technology education has an important purpose to fulfill when it comes to developing pupils' understanding of technology in everyday life, which also involves making pupils aware of sustainability issues. However, technology teaching in primary school may look very different depending on what classroom pupils enter. Many teachers are uncertain about what technological knowledge the content in the curriculum represents and what approaches characterize the subject. This has led to pupils taking part in many practical 'making' activities without understanding the technological knowledge involved (Norström, 2014; The Swedish School Inspectorate [Skolinspektionen], 2014). Furthermore, teachers feel unprepared when it comes to teaching about sustainable development (SD) (Pegalajar-Palomino et al., 2021). An important step to prevent these problems is to provide student teachers with both theoretical and practical knowledge of technology and help them transform it into Pedagogical Content Knowledge (PCK) for teaching technology. Further, education for sustainability needs to be integrated more explicitly (Pavlova, 2013; Pegalajar-Palomino et al., 2021). To take a grip on these issues we have jointly generated a collaboration between teacher educators and KomTek which is a municipal technology school that offers in-service teachers practical technology activities. The purpose is to develop a teaching module in teacher education that develops student teachers' PCK for teaching technology. This study aims to capture and understand how student teachers transform acquired knowledge and skills into Pedagogical Content Knowledge (PCK) with special attention to sustainable development.

2. LITERATURE REVIEW

2.1. Technology Education and the future technology teachers

Swedish compulsory education and teacher education are interrelated, pupils are to be educated toward curriculum goals, and teachers must be prepared by teacher education to be the facilitators of their pupils to achieve curriculum goals (Åstrand, 2023). However, a report by the Swedish School Inspectorate (2014) on technology in primary schools showed several shortcomings. Teachers feel unsure of what the content of the curriculum represents in terms of technological knowledge, as well as what approaches characterize the subject of technology. Norström (2014) suggests that it is important that technology teachers can interpret what content in the curriculum represents to be able to present high-quality technology education, as well as providing an equivalent assessment and grading of pupils (Jones et al., 2013).

Practical activities are an important element in technology education. However, teaching technology has become more defined by its practical activities in the classroom than its purpose and learning goals (Fahrman et al., 2020). As a result, there is a risk that pupils' learning of technology is limited (The Swedish School Inspectorate, 2014), as well as it becomes difficult to assess pupils' learning (Fahrman et al., 2020). The abovementioned highlights the importance of preparing future teachers with knowledge that characterizes the subject of technology. Knowledge in this sense implies conceptual knowledge, i.e., understanding technological concepts, and procedural knowledge, i.e., being able to practically take on technological tasks (McCormick, 1997). When teaching technology, teachers must be aware of, and address conceptual and procedural knowledge, as well as critical knowledge concerning the consequences of technology on our lives, on society, and the environment (de Vries, 2016). Therefore, it is of utmost importance for teacher education to prepare future technology teachers with content knowledge that includes conceptual and procedural knowledge, and knowledge of SD, as well as pedagogical competencies for teaching technology.

2.2. Transformations in technology and sustainability education

Education for sustainable development (ESD) is highly relevant to ensure that all learners can be able to contribute to achieving the global sustainable development goals (SDG). However, efforts made so far have not been sufficient (Pegalajar-Palomino, et al., 2021; UNESCO, 2018). Teachers are less prepared, i.e., lack the professional competencies needed, to teach about sustainability and sustainable ways of living (Pegalajar-Palomino, et al., 2021). Thus, key competencies including knowledge, skills ('what'), values, beliefs, and worldviews ('why') must be included as well as pedagogical competencies ('how') in teacher preparation. Pavlova (2013) argue that transformations of teaching within science and technology education are crucial. To embrace SD, it must be relevant for self or community, include practical solutions, and involve value-driven socio-scientific decision-making.

Since individual agency are crucial for SD, inner qualities and capacities for transformation have gained attention (O'Brien & Sygna, 2013; Wamsler, 2020; Wamsler et al., 2021). Inner qualities relate to the 'why' in ESD and the transformation of personal beliefs, values, and worldviews is considered the most powerful source to transform actual outcomes in practice (O'Brien & Sygna, 2013). However, the lack of individual agency is consistent, mainly due to structural constraints (Wamsler et al., 2021). A transformation of learners' mindset can be achieved in different ways, both as an end and means. In such processes, inner qualities must be addressed by giving opportunities for learners to include self-awareness, empathy, sense-making, sense of purpose, and sense of empowerment. In this study, we approach SD in line with research on ESD (e.g., Pegalajar-Palomino, et al., 2021), with particular attention to inner qualities and capacities for transformation (e.g., O'Brien & Sygna, 2013).

2.3. Pedagogical Content Knowledge (PCK)

PCK is widely used in educational research to examine the professional knowledge of teachers, as well as to examine student teachers' development of this professional knowledge. Over the years, researchers have taken a departure from Shulman's definition of PCK (1986) and developed new models of PCK. One of these, commonly used to analyse and capture teachers' PCK, is the refined consensus model (RCM). The model represents the content-specific nature of PCK when teachers engage in pedagogical reasoning during their teaching. In these situations, practical teaching activities are recognized as opportunities in which teachers' professional knowledge can be both manifested and generated (Carlson et al. 2019). The RCM makes three areas of PCK explicit (collective PCK, personal PCK, enacted PCK) as well as representing their relationships and how knowledge components of PCK flow between them. In this study, we take departure in the knowledge components of PCK in the RCM to capture and understand how student teachers transform acquired knowledge and skills into PCK when planning, enacting, and reflecting on teaching technology for primary school pupils.

2.4. Design-Based Implementation Research and Design Principles

In DBIR additional stakeholders other than the researchers are invited to the design of the research project. DBIR strives to create the conditions for studying processes that occur when stakeholders at different levels interact with a relatively clear objective of what to implement (Fishman & Penuel, 2018). In this study, we recognize that the benefits of the design process also benefit the implementation in a broader perspective. The process includes identifying design principles (DPs) that support the identification of outcomes through the course of a study (McKenney & Reeves, 2018). Within our study, the identified DPs are informed by technology education and ESD literature. In short, these are as follows:

- DP1: Basing the study within DBIR as a methodology (Fishman & Penuel, 2018)
- DP2: Supporting the establishment of iterative cooperation between stakeholders (Fishman & Penuel, 2018)
- DP3: Incorporating interior dimensions and personal values as a guide for pedagogical considerations about SD (Holbrook, 2009; Pavlova, 2013; Wamsler et al., 2021)
- DP4: Supporting transformed learning opportunities informed by PCK (Carlson et al. 2019)
- DP5: Integrating conceptual and procedural knowledge within the teaching activities (Norström, 2014; Pavlova, 2013)

3. METHOD

In this study, we present the first iteration of a teaching module in teacher education. Informed by DP1, the framework is founded upon a qualitative DBIR research methodology. This is supported by the cooperation between researchers as teacher educators and teachers at KomTek (DP2), the teaching and the assignments oriented towards teaching with pedagogical considerations about SD, the development of professional knowledge and the integration of both conceptual and practical aspects of technology teaching (DP3, DP4, and DP5).

3.1. The Educational Context and the Teaching Module Design

This study is based on a course module within a Science and Technology course of 30 credits. The student teachers enrolled in the course are preparing to become teachers in primary school, grades 4–6. In total, the course module includes 12 sessions which are divided into two theoretical blocks, one practical block, and one synthesising block (see Table 1). During the synthesising block, the student teachers are planning in groups and enact technology teaching using knowledge captured from the previous blocks.

Table 1.
Applying a DBIR framework for the teaching module in teacher education (DP3, DP4, and DP5).

Block	Content	Activities
Block 1 Theoretical Session 1–4[a]	Epistemology of technology History of technology Design and technological documentation Construction techniques, strength and durability theory, and materials	Literature seminars Group work Workshops
Block 2 Practical Session 5–8[b]	KomTek: Mechanics and Digital Models Everyday mechanics Programming	Practical technology workshops
Block 3 Theoretical Session 9[c]	Technology, human, society, and technological systems	Discussion seminars on SD, safety, ethical considerations Workshop with a debate on SD/technology, and discussions on ethical dilemmas
Block 4 Synthesising Session 10–12	Plan and teaching technology	Planning lesson: Mechanics TinkerCad Programming Electronics Lesson plan revision[d]. Perform lesson with pupils[e].

Note: [a] = 180 min each; [b] = 180 minutes each; [c] = 180 min; [d] = 180 min each; [e] = 240 min for each group, 90 min lesson with pupils.

3.2. Data collection and Analysis

The study includes two researchers as teacher educators, two KomTek teachers, and 12 student teachers. In addition, eight municipal schoolteachers, 42 4th-grade pupils, and 38 5th-grade pupils provided authenticity to the student teachers' lessons.

Data was collected in several phases of the module. Student teachers' individual written reflections on technology education and SD were captured before and after the teaching module. Further, the student teachers' lesson plans were collected. Semi-structured interviews were conducted after performed lessons. Furthermore, data were collected from the individual project assignment.

The framework for analysing the qualitative data was informed by content analysis (Selvi, 2020). Coding was carried out deductively using five PCK components derived from the research literature: Knowledge of content (conceptual knowledge, procedural knowledge, knowledge of SD); Knowledge of curriculum; Knowledge of instructional strategies; Knowledge of students; Knowledge of assessment (see Carlsson et al., 2019; Magnusson et al., 1999), and also codes for inner qualities and capacities for transformation were used (e.g., empathy, courage, relating, cooperating, critical thinking). Inner transformation involves changes in people's consciousness, and as used in this study, it describes changes in student teachers’ attitudes and related cognitive or emotional abilities (see Wamsler, 2020; Wamsler et al., 2021). To present the findings, we created vignettes as transformative accounts. However, in this paper we have chosen to present the findings based on one student teacher (Kim) who represents the inherent complexity of developing PCK for teaching technology in primary schools during the semester. Kim can be seen as an exemplifying case for the larger group of student teachers who participated in the same course.

4. RESULTS

The results show a transformative account from the student teacher Kim, in which we have outlined a course of excerpts from various data. At the beginning of the course, Kim’s individual written reflections on previous experiences of technology education and SD were collected.

> ...it was often that, as I remember the technology lessons, as the teacher might not dare to try so many new things..., we were building bridges and then we built bridges every year…

In the following excerpt, Kim presents what is important to consider when planning and teaching technology integrated with SD.

> […] You must have a good understanding of technology development concerning SD […]. You should also consider the pupils you meet by observing their interests and pre-understanding to be able to see what they need to develop […]

This initial part indicates need for knowledge e.g., ***knowledge of content*** concerning both conceptual and procedural knowledge, and about SD. Kim expresses that to implement good teaching in technology, you need to integrate knowledge of both technology and SD. Her previous experience in technology education is described as practical, limited to activities such as building bridges. However, Kim shows PCK components such as ***knowledge of instructional strategies*** and ***knowledge of students*** since she describes the importance of considering pupil’s pre-understandings and how to use this when planning teaching.

The student teachers plan lessons that they enact with pupils at the KomTek facility. Kim’s group presents a lesson where the pupils learn to produce digital models of chess-pieces in Tinker-Cad and printing it on a 3D-printer. The waste hierarchy (Lansink's ladder) is introduced to the pupils. In the group interview, Kim discusses the chess-set activity.

> I think that it feels more real when you have activities like this with the chess-game as it is a situation that they can recognize from their everyday life […].

Further, Kim discusses the way SD is connected to technology education and how a new way of thinking has occurred.

> […] I don't remember that we have encountered something like this where you must think about the materials you use or how to construct things, or think sustainably, it was new for me. [...] now it just feels obvious that it should be fitted together.

In the group interview Kim also expresses her achieved knowledge about plastic materials and recycling of plastics, which she uses in the lesson at KomTek.

> […] I had to change my thoughts a lot concerning that we think we take care of plastics very well and that we can recycle it. But then we saw that it is such a small percentage that we can take care of …

In this part, we have captured components of PCK such as ***knowledge of content*** concerning procedural and conceptual knowledge, and SD. Kim mentions especially knowledge of materials such as plastic and how this is necessary to integrate with sustainability when constructing technological solutions. She also mentions the use of practical activities that pupils relate to. This indicates that her ***knowledge of instructional strategies*** has been further developed.

In the individual project assignment, where the student teachers are expected to reflect on the lesson at KomTek, Kim elaborates on the lesson.

> The task invites discussions and reflection regarding the choice of materials, waste, and the structure of the construction with a focus on stability and durability as constructing with 3D printers makes it possible to influence these points. […] the pupils also need to develop knowledge of documentation such as sketches and digital models [...] During the work, the teacher invites to discussions about the material, structure, strength of the pieces, and the pros and cons of the production method concerning SD. […] Assessment will be made on pupils' reports and documentation in the form of sketches, digital models in TinkerCad, and finished products. All parts are assessed according to the grading criteria for the technology curriculum.

Kim's teaching idea includes several indicators of developed PCK. The PCK component ***knowledge of content*** (conceptual knowledge) is captured from her choice of contents such as the structure of the construction with a focus on stability and durability. Further, procedural knowledge is captured such as documentation in terms of sketches, digital models, and reports, and how to construct a model with a 3D printer. Also, ***knowledge of instructional strategies*** has developed. She is presenting lessons that integrate practical and theoretical sessions where pupils reflect and discuss the content and processes concerning SD. Further, she presents ways to assess pupils' learning in relation to grading criteria in the technology curriculum. This indicates that Kim also developed PCK components such as ***knowledge of curriculum*** and ***knowledge of assessment***.

After the teaching module has been carried out, Kim's individual written reflections were collected. The except below shows her new experiences and views of technology education and SD

> To be able to take a stand on issues that concern technology in relation to SD, it is important to first develop pupils' understanding of the technology that the questions concern and what its pros and cons are in relation to society, the environment, and humans.

The excerpt indicates that the PCK components' ***knowledge of content*** and ***knowledge of instructional strategies*** are present. Kim suggests that to learn and understand technology in relation to SD and being able to make well-informed decisions, it is necessary to first develop an understanding of the technology itself. Below Kim reflects on the connection between technology and SD.

> […] SD implies using and developing technology without jeopardizing the living conditions for future generations. […] I believe that the two concepts should always be connected as technology can have very negative consequences if we do not have SD in mind when we create, use, and develop the technology. […]

The vignette also shows how Kim's inner qualities are expressed. Regarding her view on the relationship between technology and SD, a transformation towards a more ***empathetic*** reasoning is present. Also, she is ***relating*** to pupils' needs for authenticity and making informed decisions in complex SD issues. During the enactment of the teaching module more arguments showing ***critical thinking*** are used.

5. DISCUSSION AND IMPLICATIONS

The results indicate two design principles in the first iteration of the teaching module that needs further attention. The first one is DP3 which is to incorporate the personal values of SD as a guide for pedagogical considerations about SD. Although the student teachers have transformed on a personal level regarding their view of sustainability in relation to technology, there are still difficulties in integrating activities that may help student teachers promote the pupils' understanding. This is evidently a persistent problem (Holbrook, 2009; Pavlova, 2013; Wamsler et al., 2021). In the first iteration, we included possibilities for student teachers to reflect on beliefs, values, and worldviews, in line with O'Brien and Sygna (2013) and Wamsler et al. (2021). In our data, several accounts support a transformation of the student teachers' mindsets, for example, increased statements that included empathy for people and nature. But still, inner qualities and capacities need additional attention to help the students address interior dimensions, which is crucial for the development of individual agency (Wamsler, 2020). Therefore, we choose to introduce lectures and inner qualities labs as off-schedule opportunities in a rearrangement of the teaching module (see Table 2).

Furthermore, there is still incoherence between the content presented and the practical activities. That is, there is a need for focus on DP5, to integrate conceptual and procedural knowledge. According to Norström (2014) and Pavlova (2013), this could be benefited from repeated practice. The re-design implies that synthesising, hence integrating, appears twice in the teaching module (Table 2). Also present in our second iteration, KomTek as cooperating stakeholders are rearranging their practical sessions informed by theoretical sessions. Such joint efforts to enhance outcomes should be beneficial (Fishman & Penuel, 2018).

Table 2.
The re-designed DBIR framework for the teaching module in teacher education

Block	Content	Activities (on schedule)	Activities (off schedule)
Block 1 Theoretical Session 1-5[a], and Inner Qualities Session 1-4[b]	Epistemology of technology History of technology Design and technological documentation Construction techniques, strength and durability theory, and materials Technology, human, society, and technological systems	Literature seminars Group work Workshops Discussion seminars on SD, safety, ethical considerations Workshop with a debate on SD/technology, and discussions on ethical dilemmas	Inner Qualities Lectures: Presence and Learning Mindset Reflective listening Sense-making Complexity awareness Inner Qualities labs: Meditation Mirroring Conscious story of life Sense of purpose
Block 2 Synthesising Session 6[c]	Introduction to planning and teaching technology	Planning lesson: Mechanics TinkerCad Programming Electronics	
Block 3 Practical Session 7-9[d]	KomTek: Mechanics and Digital Models Everyday mechanics Programming	Practical technology workshops with theoretical base from Block 1	
Block 4 Synthesising Session 10-11	Plan and teach technology	Lesson plan revision[e]. Perform lesson with pupils[f].	

Note: [a] = 180 min each; [b] = lectures, 15 min each, labs, 30 min each; [c] = 180 min; [d] = 180 min each; [e] = 180 min each; [f] = 240 min for each group, 90 min lesson with pupils.

6. REFERENCES

Carlson, J., Daehler, K., Alonzo, A. C., Barendsen, E., Borowski, A., Berry, A., … Wilson, C. D. (2019). The Refined Consensus Model of Pedagogical Content Knowledge in Science Education. In A. Hume, R. Cooper & A. Borowski, (Eds.), Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science (pp. 77–92). Springer. https://doi.org/10.1007/978-981-13-5898-2_2

de Vries, M.J. (2016) Teaching about Technology. 2nd ed. Cham: Springer International Publishing AG (Contemporary Issues in Technology Education). https://doi.org/10.1007/978-3-319-32945-1

Fahrman, B., Norström, P., Gumaelius, L., & Skogh, I. (2020). Experienced technology teachers' teaching practices. International Journal of Technology and Design Education 30, 163–186 (2020). https://doi.org/10.1007/s10798-019-09494-9

Fishman, B. J., & Penuel, W. R. (2018). Design-based implementation research. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), International handbook of the learning sciences (pp. 393–400). Routledge. https://doi.org/10.4324/9781315617572-38

Holbrook, J. (2009). Meeting challenges to sustainable development through science and technology education. Science Education International, 20(1/2), 44–59.

Jones, A., Buntting, C. & De Vries, M.J. (2013). The developing field of technology education: a review to look forward. International Journal of Technology and Design Education 23, 191–212. https://doi.org/10.1007/s10798-011-9174-4

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogical content knowledge (pp. 95–132). Kluwer Academic

McCormick, R. (1997). Conceptual and Procedural Knowledge. International Journal of Technology and Design Education, 7(1), 141–159. https://doi.org/10.1023/A:1008819912213

McKenney, S., & Reeves, T. (2018). Conducting educational design research (2nd ed.). Routledge. https://doi.org/10.4324/9781315105642

Norström, P. (2014). Technological Knowledge and Technology Education (diss). Royal Institute of Technology. https://www.diva-portal.org/smash/get/diva2:715009/FULLTEXT01.pdf

O'Brien, K., & Sygna, L. (2013). Responding to climate change: The three spheres of transformation. Proceedings of Transformation in a Changing Climate, 19–21 June 2013, Oslo (pp. 16–23). https://www.sv.uio.no/iss/english/research/news-and-events/events/conferences-and-seminars/transformations/proceedings-transformation-in-a-changing-climate_interactive.pdf

Pavlova, M. (2013). Teaching and learning for sustainable development: ESD research in technology education. International Journal of Technology and Design Education, 23, 733–748. https://doi.org/10.1007/s10798-012-9213-9

Pegalajar-Palomino, M., Burgos-García, A., & Martinez-Valdivia, E. (2021). What Does Education for Sustainable Development Offer in Initial Teacher Training? A Systematic Review. Journal of Teacher Education for Sustainability, 23(1) 99–114. https://doi.org/10.2478/jtes-2021-0008

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching, *Educational Researcher, 15*(2), 4–14. https://doi.org/10.2307/1175860

Selvi, A. F. (2020). Qualitative content analysis. In J. McKinley & H. Rose (Eds.), The Routledge Handbook of research methods in applied linguistics (pp. 440–452). Routledge. https://doi.org/10.4324/9780367824471

Skolinspektionen. (2014). Teknik—gör det osynliga synligt. Om kvaliteten i grundskolans teknikundervisning [Technology - making the invisible visible. On the quality of technology education in primary schools] (No. 2014:04). https://www.skolinspektionen.se/globalassets/02-beslut-rapporter-stat/granskningsrapporter/tkg/2014/teknik/kvalgr-teknik-slutrapport.pdf

UNESCO. (2018). Progress on Education for Sustainable Development and Global Citizenship Education. United Nations.

https://unesdoc.unesco.org/ark:/48223/pf0000266176_spa?posInSet=1&queryId=56e66126-33e0-4c4b-b491-85968586ac15

Wamsler, C. (2020). Education for sustainability: Fostering a more conscious society and transformation towards sustainability. International Journal of Sustainability in Higher Education, 21(1), 112–130. https://doi.org/10.1108/IJSHE-04-2019-0152

Wamsler, C., Osberg, G., Osika, W., Herndersson, H., & Mundaca, L. (2021). Linking internal and external transformation for sustainability and climate action: Towards a new research and policy agenda, Global Environmental Change, 71, 102373. https://doi.org/10.1016/j.gloenvcha.2021.102373

Åstrand, B. (2023). The Education of Teachers in Sweden: An Endeavour Struggling with Academic Demands and Professional Relevance. In Elstad, E. (ed). Teacher Education in the Nordic Region: Challenges and Opportunities, (pp. 75–158). Springer International Publishing. https://doi.org/10.1007/978-3-031-26051-3_4