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Development of teacher education students' pedagogical content knowledge (PCK) through reflection and a learning-by-doing approach in craft and technology education

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Abstract

The approaches of learning by doing and making have always been inherent components of Finnish craft and technology education. Craft is a practical subject that involves many hands-on activities during which students actively practice experimentation, investigation, invention, problem-solving and designing skills. The same ideology is utilised in craft and technology teacher education courses at the University of Jyväskylä. The overall purpose of this study was to increase our understanding of the development of teacher education students' pedagogical content knowledge (PCK) in craft and technology education through reflection and the learning-by-doing approach. To achieve this goal, students were asked to fill out a reflective questionnaire after one of their hands-on working sessions. The open-ended questionnaire was formulated on the basis of Roberts' (2012) four philosophical stances so that each of them were equally able to provide representative information in relation to students' reflections on it. During the academic year 2019–2020, a total of 115 students responded to the questionnaire while taking the 'Pedagogy of Multi-material Craft and Technology Basic Course'. Data were analysed by identifying themes based on the frequency of their occurrence. Philosophical stances of '*knowledge acquisition is inherently interactive'* and '*examining things based on practical consequences*' proposed by Roberts (2012) were the most evident ones in teacher education students' reflections. This study demonstrates how the learning-by-doing approach and use of a reflective tool can facilitate the development of students' PCK in craft and technology education.

Key words

Technology education, craft, learning-by-doing, reflection, PCK, teacher education

Introduction

Over 30 years ago, Brown, Collins and Duguid (1989, p. 32) raised concern on how knowledge is treated as "an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used". Saito (2018) refers to the same problem by introducing the concept of "beautiful knowledge", which means "the experience of knowing, undergoing the moment of self-transformation. More as a matter of reception rather than acquisition, it involves the experience of human transformation undergoing the phases of crisis" (p. 143.) In relation to technology education contexts, researchers have pointed out how practical learning

during technology education lessons helps students conceptualise knowledge and develop various intellectual processes (Gibson, 2019; Ritz & Fan, 2015). Furthermore, a variety of cognitive skills and higher-order thinking skills can be developed and nurtured through their application in practical contexts (Strimel, 2019; Williams, 2009, p. 248). Thus, the domain of technology education provides an important proving ground for theories of cognition, because concepts in technology are often taught through laboratory-based and other hands-on methodologies (see Hayes & Kraemer, 2017). Barlex and Steeg (2018, p. 343) describe learning as a process whereby understanding is built upon already existing knowledge. They argue that this process is most powerful when the construction environment is rich and ample opportunities are provided to view the success of one's construction efforts.

Hands-on nature and practical approaches to learning are emphasised in Finnish craft and technology education, and it is evident that the learning-by-doing approach is an inherent component of craft education (Niiranen, 2019). During craft lessons in schools, students are guided so that they can design and produce their craft products independently and/or with others by using a diverse range of techniques, tools, machines and equipment. In this pedagogical strategy, examining and problem-solving skills are seen as integral parts of learning. (National Core Curriculum for Basic Education 2014, hereinafter NCCBE 2014.) Also, the craft and technology education courses offered at the University of Jyväskylä emphasise practical approaches to learning and the pedagogy of problem solving. One of the courses is called 'Pedagogy of Multi-material Craft and Technology Education Basic Course' (3 credits). This is compulsory for all teacher education students, and after completing the course, the students are expected to achieve the following goals: 1) experience success and development of skills, 2) understand the nature of a complete craft process, 3) understand the role and importance of hands-on activities in human development and 4) develop skills to conceptualise the curriculum and utilise them when designing, developing and executing craft education. During the course, students are also expected to reflect on their positions and on the development of three different roles: the role of a craftsman/craftswoman, the role of a crafts teacher and the role of a child as an artisan.

Practical approaches to learning with reflective elements are inherent components of Finnish craft and technology education in schools, and also in courses at the University of Jyväskylä Teacher training department. For this reason, exploring and clarifying how reflective learning and its role in developing student's pedagogical content knowledge (PCK) in this context is important. Thus, the purpose of this study was to increase our knowledge and to provide information about the development of teacher education students' PCK in craft and technology education through reflection and the learning-by-doing approach. This study adds to our understanding of the learning processes wherein teacher education students are tasked to make their own projects. We also aimed to improve the practices in which reflection is being facilitated in craft and technology education.

Theoretical perspectives – reflection, PCK and the learning-by-doing approach

One major factor that brings concepts of reflective learning and pragmatism together in a significant way is that both forms of learning are relatively independent of mediation, and this extends learning beyond formal education (see Moon, 2004, p. 74). Mälkki (2011) points out that although reflection is being widely facilitated in different educational settings, what is actually gained through these efforts is not often evident. Furthermore, reflection is often

triggered by disorienting dilemma or a growing sense of dissatisfaction; however, how this would lead to reflection has yet to be fully explained (Mälkki, 2011). Considering the academic context, reflection and reflective learning are likely to involve a conscious and stated purpose for the reflection, which can yield specific outcomes in terms of learning, action or clarification (Moon, 2004, p. 83). Tracey and Hutchinson (2018) note that reflecting for and from action is relevant in design education, as the goal should be to prepare students for what they will encounter in their future professional practice.

When considering teacher education, the idea of reflection is strongly related to the development of teachers' PCK. As Hashweh (2013, p. 120) proposes "we think of PCK as a set or repertoire of personal content-specific pedagogical constructions which teachers develop as a result of repeated planning, teaching and reflection on the teaching". Although it is difficult to distinguish PCK from other fields of knowledge that teacher displays in teaching (general pedagogical knowledge, subject matter knowledge and knowledge of context) (Gess-Newsome, 1999), patterns help us to analyse the activities or the ways that the development of teachers' PCK could be supported. In their study on primary school teachers' development of PCK in a design-based research project, Hultén and Björkholm (2016) underlined the importance of reflection on one's own actions, making teachers owners of their professional development, in collaboration with others.

There are seven teacher key competence areas that are defined in Teacher education curriculum, University of Jyväskylä 2020–2023. These competences create guidelines to be considered throughout training in teacher education. One of the competences is namely "Pedagogical competence" (competence area 5). According to this competence area, students should be able to: 1) plan, implement, differentiate, evaluate and develop various learning processes, 2) understand the connection between learning objectives, pedagogical activities and assessment in interactive learning and guidance processes, 3) act and think creatively and innovatively and 4) be open to new perspectives, invent, experiment and challenge the familiar. (Teacher education curriculum, University of Jyväskylä 2020–2023.)

Four philosophical stances of learning by doing

Undoubtedly, John Dewey (1859–1952) is one of the most significant figures in the field of experiential education, particularly amongst classical pragmatists; he is known for demonstrating most concretely the contemporary significance of the *praxis* of pragmatism for the reconsideration of useful knowledge and education (Saito, 2018). The concept of pragmatism has been divided into four philosophical stances (Roberts, 2012, p. 49), which are understood to loosely define it. The first stance concerns *examining things based on practical consequences*. In other words, one chooses a course of action according to the likelihood of its success or with an awareness of the consequences of one's actions (Roberts, 2012, p. 50). Learning by doing, in the context of craft and technology education, is accentuated by activities involving problem solving, design and scientific inquiry. The design process in craft and technology education is usually characterised as a goal-directed and iterative activity, whereby the designer learns about the problem by proposing solutions and synthesising ideas (see Purzer, Goldstein, Adams, Xie, & Nourian, 2015).

The second stance of pragmatism (Roberts, 2012, p. 51) states that pragmatists understand that thinking cannot be removed from the world, because *knowledge acquisition is inherently*

interactive. This means that the interactions between thinking and action and how they revise one another are seen as key factors in learning (Roberts, 2012). Thus, the learning process is highly contingent upon interactions with the environment and the people who are related to it. The role of context is of central importance in craft and technology education, wherein interactions with tools, concrete objects and materials offer a potentially supportive environment for collaborative actions (see Hennessy & Murphy, 1999).

The third stance of the pragmatist ethos, *the importance of context* (Roberts, 2012, p. 52), also relates to the learning environment. As described previously, in order to consider practical consequences interactively, one must be situated somewhere. It has been argued that situativity is a dominant perspective in technology and engineering disciplines—one that emphasises the role of the environments and requires extensive content knowledge and analytical skills to engage in learning (Hennessy & Murphy, 1999; Johri & Olds, 2011; Pleasants & Olson, 2018). Problem solving, project-based learning and creating things with the use of one's hands are evidently inherent components (i.e. methods for learning) of craft and technology education (Niiranen, 2019; Kilbrink, Bjurulf, Blomberg, Heidkamp & Hollsten, 2014), and each of these pedagogical approaches is innately contextual. Thus, when learning is grounded within a specific context, it is often authentic, relevant and representative of an experience that may be found in practice (Kelley & Knowles, 2016).

The fourth stance of the pragmatist ethos is *fallibilism* (Roberts, 2012, p. 52), which means that errors are seen as part of the learning process and are an inherent part of technology education. This idea relates to an interesting characteristic of technology education: the high degree of tacit knowledge inherent in it. Tacit knowledge and skills, i.e. understanding how various materials behave and knowing how to manipulate them, can be gained only through concrete experience, although some errors are often made during the process of making. The concept of tacit knowledge also adheres to the concept of embodied cognition as both emphasise the body's role in forming cognitive representations. By action, one's cognitive systems are affected—even constrained—and these sensorimotor processes, including perception and action, strengthen learning when included in a structured lesson because of their close and unique relationship to the cognitive system (Weisberg & Newcombe, 2017). As Gibson (2019, p. 27) describes, tacit learning happens most often 'on the job'. Thus, hands-on activities are sometimes seen as a 'black box' in learning, and what students have actually learnt might be hidden (Kuen-Yi & Williams, 2017).

Research design

The aim of this study was to increase our knowledge and to provide information about the development of teacher education students' PCK in craft and technology education through reflection and the learning-by-doing approach. Data were collected by using an open-ended reflection questionnaire distributed to students enrolled in the 'Pedagogy of Multi-material Craft and Technology Basic Course'. Students were asked to provide reflections on an optional questionnaire (in paper) at the end of one three-hour hands-on working session (8th session). The open-ended questionnaire was formulated on the basis of Roberts' (2012) four philosophical stances and the questions were designed to provide equally representative information, with three questions per stance, concerning their special nature (see Table 1). In the questionnaire, there were 12 open-ended questions to choose from, and the students were encouraged to answer multiple options (i.e. to report all they could recall). No identification

information was asked from the participants. During the academic year 2019–2020, between 3.9.2019–13.3.2020, a total of 126 classroom teacher education and special education students (eight groups) signed up to participate in the course. Almost all (91%) of the students responded to the questionnaire.

Table 1. Four stances of learning-by-doing by Roberts (2012) and the questions modified for the craft and technology education students (see also Niiranen, 2019).

Examining things based on practical consequences
One chooses the right course of action based on the likelihood of success, or with an awareness of the consequences of one's actions. In craft and technology education, learning by doing is accentuated by activities involving problem solving, design and scientific inquiry.

Q1 I solved a problem: *What kind of problem?*
Q2 I chose one technique from many options: *Which one and why?*
Q3 I ended up doing something contrary to my plan: *What did I change?*

Knowledge acquisition is inherently interactive
The interactions between thinking and action and how they revise one another are seen as key factors in learning. Thus, a learning process is highly contingent upon interactions with the environment (craft and technology education classrooms) and the people who are related to it.

Q4 I asked for help from others: *What did I need help with?*
Q5 I helped someone to make something: *How did I help?*
Q6 I designed or developed my work together with others: *What did we design?*

Fallibilism
Errors are seen as part of the learning process and an inherent component of technology education. High degrees of tacit knowledge and skills, i.e. understanding how various materials behave and knowing how to manipulate them, can only be gained through concrete experience.

Q7 I made a mistake in measuring or marking: *What kind of mistake did I make?*
Q8 I chose a wrong tool: *What happened?*
Q9 I made some other kind of a mistake: *What kind of mistake did I make?*

Importance of context
In order to consider practical consequences interactively, one must be situated somewhere. Situativity is a dominant perspective in technology and engineering disciplines. Problem solving, project-based learning and creating things with the use of one's hands are inherently contextual.

Q10 I learnt to use a new tool: *Which tool?*
Q11 I used some machines during working: *Which machines?*
Q12 I learnt something about the properties of materials: *What did I learn?*

The syllabus of 'Pedagogy of Multi-material Craft and Technology Basic Course' includes 10 sessions (3 hours per session), which are compulsory for all students. The course consists of various modules, such as a module involving a hands-on working session, wherein students implement their projects in technical and textile craft workshops. The logic for choosing the 8th session, i.e. one of the hands-on sessions, to conduct this study was due to it being the first session, where students will actively start to implement their individual projects. During previous sessions, students have familiarized themselves with the various craft (textile and technical) materials, tools, techniques and machines on a general level. Thus, they should be able to use them rather independently when working with their projects. The overall idea in the 8th session is that students are encouraged to independently use all necessary materials, tools and machines to implement their projects and to solve various authentic open-ended problems in collaboration with peers. While students are working, they are guided to take ownership of both implementing their own craft project and developing their personal pedagogical content knowledge in craft and technology education. The teacher's role is to supervise students in terms of work safety and to give guidance and support when it is needed.

As the research approach was theory-driven and has fairly clearly defined attributes, a quantitative approach was used to analyse the data. The primary aim was to investigate and discover themes based on the frequency of their occurrence. Quantitative content analysis was chosen to be the analysis method as it enables the illumination of patterns in a larger set of communication content in a reliable way (Rourke & Anderson, 2004). By doing so, data comprising 115 students' written responses were analysed using the frequentist descriptive method, which aimed to identify students' descriptions concerning questions 1–12. First, all responses to a single item were read through and students' responses were calculated as frequencies in relation to how many of them answered each question (see Fig 1). Then, meaningful descriptions or manifest content were chosen as the analysis units and those were listed by assigning each contribution under a category. During this coding process, the researcher used both quantitative and qualitative analyses to process the survey items in order to develop the categories. This was done to ensure that the students' responses were appropriately captured. After the coding, the categories were grouped into sub-themes, which emerged from the data. Such a content analysis, in order to be reliable, requires that the coder understands the context i.e. how to identify behaviours and the representative samples that represent the construct (Rourke & Anderson, 2004, p. 9). In this study coding was performed by a researcher who knows the context of the study well as she has acted, in previous years, as a teacher in the course. The identified sub-themes within each question (1–12) and their relations with the four philosophical stances proposed by Roberts (2012) will be presented in the results section.

Results

The following findings are tied to certain elements and contexts wherein students were asked to provide reflection at the end of a three-hour hands-on working session in the 'Pedagogy of Multi-material Craft and Technology Basic Course'. The projects that students were working on included the use of basic hand tools, such as hand saws, chisels, mechanical drills, hammers and screw drivers. Many woodworking techniques were used (e.g. making a nail/screw or doweled joints, welding, turning wood), and some students have also chosen textile techniques (e.g. knitting and sewing). Students used various machines, such as drilling and sanding machines, band saw, thickness planer for wood and lathe while working. In the following section, four

philosophical stances of learning by doing and the findings of the reflective questionnaire are presented.

When investigating students' responses to the reflective questionnaire 'What did I do in today's craft education contact session'? the questions with the highest frequencies were questions 4, 5 and 6 with altogether 282 responses (see Fig 1). These three questions reflected the second stance of pragmatism, namely, *knowledge acquisition is inherently interactive* (Roberts, 2012). Almost all (93%) of the students provided reflections to the question 4 (I asked for help from others: What did I needed help with?). Based on the students' reflections the most representative sub-theme was 'Using the woodworking machines'. The second most representative sub-theme was 'Performing a technique with a certain material and how to proceed with working'. As evidenced in a previous question, whether students asked for help from others, reflections on question 5 revealed that they also helped each other. Many (82%) of the students answered question 5 (I helped someone to make something: How did I help?). The most representative sub-theme was 'With the use of the woodworking machines' and the second most representative sub-theme was 'With the design or working with the different tools and techniques'. Also, many (70%) of the students responded to question 6 (I designed or developed my work together with others: What did we design?). The most representative sub-theme in relation to this question was 'Planning collaboratively how to implement the project' with the next one being 'Designing the project together'.

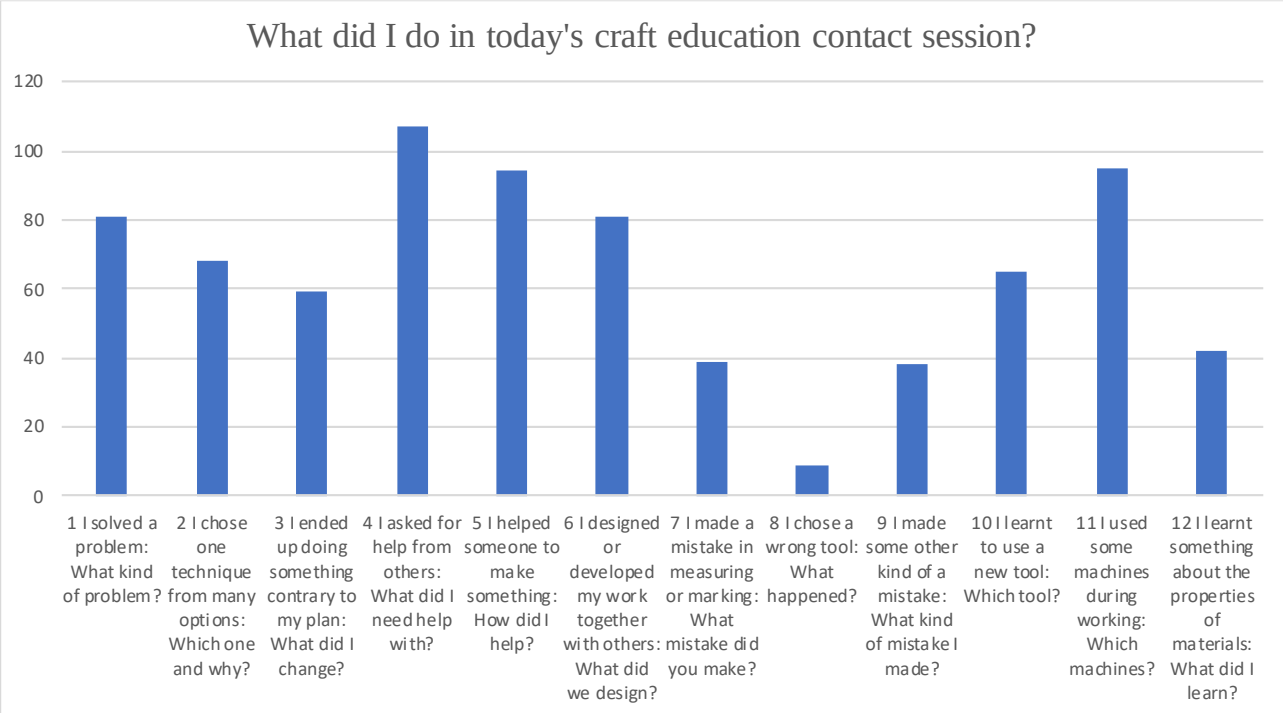

Figure 1. Students' responses to the questionnaire items (N=115)

The second highest frequencies were calculated with questions 1, 2 and 3, altogether 208 responses. These questions reflected one of Roberts' (2012) philosophical stance of pragmatism, namely *examining things based on practical consequences* (see Fig 1). Many (70%) of the students responded to question 1 (I solved a problem: What kind of problem?). Based on the students' reflections, the most representative sub-theme was 'Ideating and designing the

project (materials, measurement)'. The second most representative sub-theme was 'How to implement the technique by using a machine. The ideas were related for solving the problem related to a specific technical question, like how to saw the pieces, drill a hole or smooth the wood, use the right kind of sanding machine, turn wood or how to knit or sew and when students needed to use various machines or tools for making something. More than half (59%) of the students answered question 2 (I chose one technique from many options: Which one and why?). The most evident sub-theme was 'To use a machine in order to implement the technique better and faster'. Other reflections for this question were mainly related to the sub-theme 'Trying some different techniques and tools'. Also, half (51%) of the students responded to question 3 (I ended up doing something contrary to my plan: What did I change?). The most representative sub-theme was 'Finding some new ideas, whilst working on the project'. These ideas were related to using a different way to fasten the pieces, making smaller/bigger projects or changing the material and/or the surface treatment in their project.

In relation to the stance of *the importance of context* (Roberts, 2012) (questions 10–12), there were altogether 202 responses. Concerning students' reflections on question 10 (I learnt to use a new tool: Which tool?), more than half (57%) of the students responded that they became more familiarised with and confident in using the machines; however, these machines were not new for all students. The same can be evidenced when many (83%) of the students answered question 11 (I used some machines during working: Which machines?). The use of various machines depended on the project. However, for many projects, it was necessary for students to use common ones, including the thickness planer, band saw, drilling machine, sanding machines and some used the mechanical jigsaw, lathe, laser cutter or welder. In addition to using machines and hand tools, some students (37%) answered question 12 (I learnt something about the properties of materials: What did I learn?). Naturally in this context, these reflections mainly concerned the properties of wood (pine of plywood) and some about metals (aluminium and steel) or textiles.

There were also three questions (7, 8 and 9) related to *fallibilism* (Roberts, 2012). Some (34%) of the students responded to question 7 (I made a mistake in measuring or marking: What kind of mistake did I make?). The students wrote such comments as: *"I had measured one piece of my project too long", "I measured incorrectly and had to saw again", "The hole came a little wrong when I didn't measure carefully enough" and "At the point when I was trying to start with old measures, I marked sawing places that weren't worth taking".* Only a few (8%) answered question 8 (I chose a wrong tool: What happened?). Those who reported something related to this question had chosen a right kind of tool or machine for making something, but it proved inadequate at some point (e.g. the file was too rough or the piece to be sawed was too huge for the band saw). Some (33%) of the students responded to question 9 (I made some other kind of a mistake: What kind of mistake did I make?). Students made reflections through the following comments: *"I sawed too close to the marked line and the piece got smaller", "I sanded one corner too much so it became a bit different", "I sawed the piece before using the thickness planer, so I had to make new on", "I should have supported my work better, so there wouldn't have been that ugly mark. By sanding, however, it got better" and "I burned the pattern unevenly when inadvertently the wood burning pen was too powerful".*

Reflective questionnaire as a way to support students' learning in craft and technology education

One philosophical stance (i.e. *knowledge acquisition is inherently interactive*) proposed by Roberts (2012) appeared to be the most evident in teacher education students' reflections when they responded to the questionnaire after their hands-on working session. Almost all students (93%) reported asking for help from other students for using the machines that they needed for their work or for instructions regarding performing a technique with a certain material they were unfamiliar with. In addition to that, many (82%) reported that they helped others with the use of the woodworking machines, and/or with the design or working with different tools and techniques. Also, many (70%) of them reported that they planned collaboratively on how to implement their projects (e.g. in terms of its structure and the design). This finding supports the idea that problem-based learning can facilitate knowledge transfer, encourage and support collaborative work and improve students' thinking and designing skills (Fain, Wagner & Vukasinovic, 2016). Also, as today's learning environments and pedagogical decisions should support the use of modern teaching and learning processes and when students are encouraged to work like this, they are prepared to understand the role of a teacher and peer-interaction during an authentic problem-solving process. Thereby, we claim that this type of working will help students to develop their PCK in craft and technology education.

In relation to the philosophical stance of *examining things based on practical consequences* (Roberts, 2012), we found that this was also strongly present in students' responses. Many (70%) of the students reflected that they solved problems related to ideating and designing the project and/or how to implement the technique by using a machine. Furthermore, over half (59%) of the students reported using machines in order to implement the technique better and faster and/or that they tried some different techniques and tools. Also, a little over half (51%) of the students reported that, whilst working on their project, they found some new ideas (e.g. a different way to fasten the pieces) or they ended up making smaller/bigger projects or even changing the material and/or the surface treatment of their project. As making and practical approaches to learning are emphasised in the NCCBE 2014 craft subject (Niiranen, 2019) and at the University of Jyväskylä craft and technology teacher education, this finding supports the view that through the learning-by-doing approach, students can be encouraged for problem solving and systematic inventive thinking (see Barak & Albert, 2017). Although this finding revealed that more than half of the students recognize and solve problems during working with their project, we cannot be sure how they understand the pedagogical aspects of a problem-solving process and which are those key questions that teachers should take care of when planning activities for their pupils. As teacher educators, we might lean too much with the idea that students make connections themselves of their own working and with the pedagogical aspects i.e. they read the 'hidden curriculum' of the 'Pedagogy of Multi-material Craft and Technology Basic Course'. Thus, in order to emphasize the pedagogical aspects and help students to better develop their PCK, we should add stronger links with the pedagogical aspects by making them more visible in students' reflections.

There are some limitations in this study and in order to understand how to better support students for developing their PCK, more research is needed. On one hand, this study was limited to investigate students' reflections in written form on paper. Future research may

include interview as a data collection method to elicit students' reflections on the development of their PCK. Besides, future studies can be conducted to investigate how a reflective questionnaire would be utilized in various ways, in an electronic form, during the 'Pedagogy of Multi-material Craft and Technology Basic Course' or other courses.

These findings provided an important contribution by explaining the conceptual connections amongst the cognitive and social aspects of craft and technology education in teacher education. Using this kind of reflective questionnaire as a research tool offered us a way to improve our educational practices to further develop also students PCK. In order to ensure this, we will add some pedagogically oriented questions e.g. 'What did I learn pedagogically in today's craft education contact session?' to the reflective questionnaire in the following academic year. In addition to that, at the end of the course, students will be asked to write reflections on the development of their pedagogical competence in relation to craft and technology education course to their electronic professional development portfolio (Prope). Finally, as a recommendation for technology educators, by emphasizing a learning-by-doing approach with reflective elements, students' PCK and thereby also pedagogically oriented key questions can be made more visible and a stronger part of craft and technology education.

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