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Emerging imbalance in the development of TPACK - A challenge for teacher training

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Abstract
This research continues the tradition of Technological Pedagogical Content Knowledge (TPACK) studies aimed at better understanding the development of pre-service teachers' TPACK. The aim of the study is to show what are the areas of TPACK that pre-service teachers perceived as important and relevant for them, from a teacher training course. This course can be seen as a one of the many teacher training courses within teacher training. The course is not specially designed for mere educational technology, instead the course focuses on biology, using inquiry-based learning activities supported with various technologies. This study was conducted using qualitative methods. The research data consists of pre-service teachers' (n = 165) answers to two short questions focusing on the elements that pre-service teachers gained from a teacher training science course for building their TPACK. The aim of this method was to highlight only the area that pre-service teachers felt important and relevant without providing any guiding structures. Results show the important role of Pedagogical content Knowledge (PCK) as the core area that respondents gained from the course. The results indicate that the role of Technological Pedagogical Knowledge (TPK) remained modest, the number of responses focusing on TPK was low, and the responses remained at a very general level. The results suggest that in order to provide pre-service teachers with better and more balanced support for the development of their TPACK, we need to highlight technology and make its role more explicit, especially from the perspectives of teachers.

Keywords TPACK · Teacher training · Pre-service teacher · Authentic experiences · Educational technology

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1 Introduction

The field of educational technology is a fast-evolving area (Weller, 2020). New technologies, applications, and gadgets, along with new pedagogical ideas, present teachers with novel possibilities to construct learning environments for different learning needs (Freeman et al., 2017). During teacher training, pre-service teachers are expected to gain the skills and readiness to use technology in their future work as teachers. Tondeur et al.'s (2012) Synthesize Qualitative Data (SQD) framework outlines six core strategies for how to make this happen. The six strategies emphasize: (1) teacher educators as role models, (2) reflection about the roles of technology in education, (3) learning technology by designing, (4) collaborating with peers, (5) scaffolding authentic technology experiences, and (6) continuous feedback. These areas highlight the importance of constant Information and Communication Technology (ICT) integration for teacher training via skilled teacher trainers. Pre-service teachers need to be in an active position to design, collaborate, and reflect on the use of ICT in education. Similarly, Valtonen et al. (2015) argued that, via authentic learning experiences within well-designed courses using ICT, pre-service teachers gain confidence in their skills to take advantage of ICT in education. Hofer and Grandgenett (2012) suggested that teacher training is often understood as the key catalyst in the preparation of new teachers as skilled users of ICT in education. Even though the important role of the teacher training and the methods for providing pre-service teachers with skills and willingness to use ICT in education are well acknowledged, the results are still not as positive as one might expect (Gudmundsdottir & Hatlevik, 2018; OECD, 2019; Tondeur et al., 2017).

To provide new teachers with the readiness and willingness to use technology in their future work, pre-service teachers are provided with several courses designed and conducted to (more or less) align with the principles of the SQD (Tondeur et al., 2012). Teacher training contains technology-specific courses (i.e., courses that are focused only on certain technologies and skills to use those technologies) and courses combining technology with certain pedagogical approaches without any certain content areas. Along with these technology-specific courses, teacher training contains numerous courses focusing on subject matter content taught in school, such as mathematics, arts, and history, along with other topics related to teachers' work, such as educational psychology, ethics of education, research methods, and so on, where the use of technology is targeted more at supporting the learning processes and content knowledge than technology. According to Wang et al. (2018), Graham (2011), and Hofer and Grandgenett (2012), subject matter courses where technology is integrated in pedagogically meaningful ways are the most beneficial way to provide pre-service teachers with readiness to use technology for teaching and learning, suggesting that technology should be infused into the entire teacher training curriculum.

Pre-service teachers' readiness for using ICT in education has been actively studied using various theoretical frameworks, such as the TPACK framework developed by Mishra and Koehler (2006). TPACK is a framework for studying pre-and in-service teachers' knowledge related to the skilled use of ICT in education. The framework is built on three foundational knowledge areas: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), and three combining areas: technological pedagogical knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK) (Koehler et al., 2013). The TPACK framework has been used in several studies conducted with various methods to understand the development of pre-service teachers' TPACK (Wang et al., 2018; Willermark, 2018). Within this study, we continue this tradition, building on an understanding of the development of pre-service teachers' TPACK. Within this study, we provide a new perspective on the topic by focusing on pre-service teachers' experiences of a typical subject matter course built on the active use of technology using inquiry learning as the main pedagogical approach. This study focuses on areas of TPACK as building blocks for developing TPACK that pre-service teachers perceived to have gained from this course.

2 Theoretical background

This research is grounded on Mishra and Koehler's (2006) TPACK framework. The TPACK framework was built on the PCK framework by Shulman (1986). PCK is knowledge combining CK, a deep understanding of the subject matter taught at schools, and PK, the understanding of learning theories and teaching and learning practices. PCK is the knowledge of transforming the subject matter knowledge best suited for teaching and learning and organizing the conditions that enable the students' learning (Chai et al., 2013). The TPACK framework extends the PCK framework with TK emphasizing the role of technology (Mishra & Koehler, 2006). Altogether, the TPACK framework contains seven knowledge areas—TK, PK, and

Table 1 TPACK areas, aligning with the articles by Koehler et al. (2013) and Koh et al. (2013)

TPACK areas	Description
CK	Refers to knowledge about subject matter knowledge, containing the main theories, concepts and practices in the field i.e., the core areas of the discipline.
PK	Refers to knowledge about teaching and learning practices in general such as classroom management, students' knowledge construction and assessment.
TK	Refers to knowledge about the technology in general, understanding the possibilities of technology, knowledge needed to keep up with the fast development of technology.
PCK	Refers to knowledge of how to combine the content area knowledge with pedagogical knowledge in order to make the content knowledge easy to learn and understand for students.
TCK	Refers to knowledge about technologies that are used within certain discipline in order to further develop the discipline.
TPK	Refers to knowledge about teaching and learning with technology in general, what are the benefits and limits of technology for learning, what are the most suitable technologies for certain pedagogical aims.

CK—and their combinations of PCK, TPK, and TCK (more detailed descriptions in Table 1.). Altogether, these areas combine to become TPACK (i.e., "an understanding that emerges from interactions among content, pedagogy, and technology knowledge […] knowledge underlying truly meaningful and deeply skilled teaching with technology" (Koehler et al., 2013)). As a theoretical framework, TPACK emphasizes the importance of all knowledge areas as part of pedagogically meaningful teaching with technology (Petko, 2020). Also, according to Doering et al. (2009) and Valtonen et al. (2020), TPACK should be considered an evolving entity with unique combinations of stronger and weaker TPACK areas.

The nature and development of pre-service teachers' TPACK have been studied in several articles using different methods (Willermark, 2018). Studies have been conducted using various self-assessment instruments in which the target group assesses their confidence related to the different TPACK areas (Baran et al., 2011; Chai et al., 2010; Schmid et al., 2020a, b; Valtonen et al., 2018). The results of these studies provide a rather inconsistent picture of pre-service teachers' perceptions of their knowledge, outlining a rather complex picture of pre-service teachers' TPACK. In order to better understand ways to support the development of pre-service teachers' TPACK, Lachner et al. (2021) studied the effects of a short TPACK module targeting a subject-specific course during teacher training. The module was designed in line with the six SQD strategies. Their results indicated positive effects for pre-service teachers' content-specific TPACK, but not for the general level of TPK. Within the study by Mouza et al. (2014), the effects of the educational technology course for pre-service teachers' TPACK was studied. The course was designed to meet the six strategies of the SQD framework. The results, measured with a self-assessment instrument, indicated that the biggest changes were in pre-service teachers' TCK, and altogether, the highest assessments were for TPK. Similarly, Hsu and Lin (2020) studied the effects of a four-week training module designed to meet the SQD strategies of pre-service teachers' TPACK. Again, the results from pre-and post-test scores indicated positive results from all measured TPACK areas. Altogether, these results provide a positive picture of the possibilities of well-designed instructional interventions to support the development of pre-service teachers' TPACK.

Along with specific interventions to support the development of pre-service teachers' TPACK, the topic has been studied using longitudinal approaches. A four-year longitudinal study by Gill and Dalgarno (2017) showed differences among the target group of pre-service teachers and highlighted the important role of teacher trainers and learning experiences with technology (Gill & Dalgarno, 2017; Hofer & Grandgenett, 2012) targeted the development of 17 pre-service teachers' TPACK during a 3-semester (11-month) study period. The biggest gains were within the combined areas, especially TCK, TPK, and TPACK. The development within the core TPACK areas, CK, PK, and TK, was more moderate. The study by Valtonen et al. (2019) focused on the development of 147 pre-service teachers' TPACK areas during the first 3 years of teacher training. Their results showed that the highest starting level and the highest gains were for PK. In addition, other PK-related areas had increased development and higher starting levels than technology-related areas. In particular, self-assessed TCK started and remained low during the three-year period.

Results of previous TPACK studies showed that pre-service teachers are a rather heterogeneous group. In a study by Schmid et al. (2020a, b), pre-service teachers were divided into groups based on their self-assessed TPACK. The results showed a model in which respondents were divided into two groups, one with high assessments and one with low assessments. Assessments were conducted with the instrument using a 1 to 5 scale; the mean values of the high-assessed group were near 4, and those of the low-assessed group were close to 3. This indicates a clear difference between the groups. Again, they continued the clustering of respondents, ending up with five groups with finer-grained differences. In addition to all low and all high groups, this clustering resulted in a group with low TK, one with low CK, and one with low PK. Similarly, in a study by Valtonen et al. (2018), pre-service teachers were clustered using a self-assessment instrument. The results ended up in four clusters, aligning with the results of Schmid et al. (2020a, b) showing groups with high assessments for all TPACK areas and a group with low assessments for all TPACK areas. In addition, between these groups, there was one group with low TK areas (TK, TCK, and TPK) and one group with strong confidence in their TPK. Tondeur et al. (2017) studied pre-service teachers' readiness to integrate technology into teaching and learning activities, using TPACK and other ICT-related characteristics, such as attitudes toward the use of ICT in education and ICT self-efficacy. The study was conducted using a self-assessment instrument. Aligning with Schmid et al. (2020a, b), they ended up with two groups with high and low profiles and statistically significant differences in all measured areas.

These results show that different interventions have positive effect on supporting the development of pre-service teachers' TPACK. Again, the longer effects of teacher training on pre-service teachers' TPACK seem more diverse, still the development exists. This paper takes a new stance on the topic, instead of assessing the effects of a certain specially designed intervention type course focused on technology and TPACK we take the perspective named as authentic integration of technology. With the authentic integration we refer to courses that takes advantage of the technology as a means for learning, still targeting other content areas, in this case biology. The aim of the authentic integration is to emphasize and understand the role of these courses that are not specially targeting technology nor TPACK, the courses that are in major role in teacher training. The effects of these courses reflects within the results of the longitudinal studies (Valtonen et al., 2020), still their role as the target of research has been limited within the TPACK literature. Also, instead of using methods that directs respondents' attention to all areas of TPACK such as questionnaires with all areas as their own statements, we aim to highlight what are the TAPCK areas that respondents find important and relevant for their profession.

Pre-service teachers' readiness for using ICT in education has been actively studied using various theoretical frameworks, such as the TPACK framework developed by Mishra and Koehler (2006). TPACK is a framework for studying pre-and in-service teachers' knowledge related to the skilled use of ICT in education. The framework is built on three foundational knowledge areas: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), and three combining areas: technological pedagogical knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK) (Koehler et al., 2013). The

TPACK framework has been used in several studies conducted with various methods to understand the development of pre-service teachers' TPACK (Wang et al., 2018; Willermark, 2018). Within this study, we continue this tradition, building on an understanding of the development of pre-service teachers' TPACK.

3 Methods and research questions

Tondeur et al. (2019) considered teacher educators to be gatekeepers for providing new teachers with qualifications for using ICT in education. This study can be considered a case study targeting the authentic integration, representing a teacher training course within the context of Finland i.e., not a course focusing just on learning technologies. The focus course is Inquiry-Based Science Education, a five-credit teacher training course conducted in the spring of 2019. This course is one of the so-called *multidisciplinary studies* courses that focus on different discipline areas taught in elementary-level schools, such as arts, history, mathematics, geography, Finnish, and literature. These courses are compulsory for qualifying to teach pupils in grades one through six. Courses are targeted at learning to apply and combine the contents of different disciplines with PK, and gaining an understanding related to the specific features of teaching the contents of the specific discipline.

These courses cover about one-third of all teacher training for primary school teachers in Finland, providing an important element for supporting the development of pre-service teachers' TPACK. We use the concept of authentic integration to refer the courses like this i.e., the courses that play a major role within teacher training, the courses that are not specially targeted for educational technology but still uses technology supporting learning certain contents, like biology in this case. We see that it is important to understand how the courses of these kinds, the majority of courses in teacher training, show in the development of TPACK. This is the goal of this paper. We assume that the development of TPACK does not come only from technology courses or courses otherwise targeting technology, we assume that also the other courses are highly relevant to the development of TPACK, especially the ones targeting certain content areas like biology. In addition, these courses are rather large, based on the number of participants, providing possibilities to cover the entire yearly cohort of pre-service teachers within one Finnish teacher training department.

The aim of this research is to focus on one of these multidisciplinary courses in order to understand their potential for supporting pre-service teachers' developing TPACK. The research questions are:

> How different TPACK areas are acknowledged, what are the TPACK areas that pre-service teachers perceived relevant for their future profession?
> How the TPACK framework appears as a whole, how balanced the different TPACK areas are within pre-service teachers' responses?

The target course contained 6 h of lectures and 16 h of exercises. Most of the exercises (14 h) involved using different inquiry methods to study biological structures and processes; these studies were conducted face-to-face in a

Table 2 Structure of the course

Topic	Description of inquiry	Duration
1. Plant and animal cells	-examination of constituent parts cells using microscopes -functions of cells, organs, and organ systems	2 h
2. Plant anatomy and structure/morphology	-classification of plants -structure of flower -plant breeding systems	3 h
3. Water and nutrient supply in vascular plants	-how plant roots and leaves absorb water/nutrients -function of stomata -photosynthesis and respiration	3 h
4. Fish anatomy and physiology	-classification of animals -fish anatomy -adaptations for water	3 h
5. Egg	-examination of hen's egg - -development stages of chicken	2 h
6. Technology-mediated nature trail: biodiversity	- dimensions of biodiversity - human impact on biodiversity - how to estimate biodiversity -species identification	3 h

laboratory class (more details in Table 2). The course was designed following the principles of inquiry-based learning (Minner et al., 2010; Pedaste et al., 2015). According to inquiry-based learning, the learning process is seen as a cyclic entity, starting with the orientation phase for generating research questions and triggering curiosity about the topic. The learning process continued to the phase where experiments are designed and carried out, allowing students to collect and analyze data and draw conclusions. The next phase involved communicating the findings and experiences with their peers and building ideas and questions for the following inquiry cycles. Again, the course was designed to take advantage of different technologies for supporting the inquiry process, especially for planning and organizing the work and making the inquiry process and the content studies concrete and visible as sources for the collaborative learning processes. For these aims, Microsoft cloud services were used for collaborative knowledge construction, both in small groups and with the whole class. During the exercises, smartphones, laptops, and digital microscopes were used to take and edit photos, make mind maps, and model biological structures and processes. Students worked in small groups and captured the learning process and content of inquiry in Microsoft OneNote. A short feedback session was held immediately after each inquiry or at the beginning of the next exercise. The last exercise included a technology-mediated nature trail, where smartphones were used to scaffold learning. The predefined activities allowed students to find their path and the checkpoints (digital maps, location), receive instructions, assignments, or hints for the activities, submit answers, and receive feedback (Google Forms). This allowed the teachers to scaffold the investigation through structuring and problematizing. Students were free to choose a suitable time and group for their nature trail visit as long as they did it before a common feedback session for each class. The course was graded based on a test covering both lectures and exercises.

The target group for the research consisted of pre-service teachers (n = 165) participating in the course described above. Altogether 198 pre-service teachers were listed for the course, 165 provided permission for research and participated for all the needed course activities. The majority of the pre-service teachers participating were female 121 (73%), and the rest 44 (27%) were male. The use of a course containing a cohort of pre-service teachers (the target group) aligns with a purposeful sampling method for selecting participants (Cresswell & Plano Clark, 2010). According to Creswell and Plano Clark (2010), one goal of purposeful sampling is to choose participants who are expected to have maximum differences in their perspectives on the topic. Within this case, based on previous studies, we assumed that from the participants, covering a whole cohort of pre-service teachers, we could interact with pre-service teachers with different TPACK profiles (Schmidt et al., 2020a, b; Valtonen et al., 2018). These pre-service teachers will graduate with a master's degree in education, providing them with a qualification to teach pupils from grades one through six. The research was conducted in alignment with instructions from the Finnish National Board on Research Integrity (TENK, 2019). Permission to conduct the research was acquired from the head of the department. Participation in the research was voluntary; all participating pre-service teachers were well informed about the research, and informed consent was obtained from all participants. Data were collected using an online questionnaire. The main data used within this research consisted of responses to two open questions: (1) From the perspective of your development as a teacher, name the three most important things that you gained from this course. (2) If you were teaching similar biology content to grades three through six at your elementary school, what methods, materials, tools, and environments would you use? The aim with these two open questions was to trigger pre-service teachers' reflective thinking about the course at general level. We assumed that the separate questions for each TPACK areas would have posed a risk for getting the answers that respondents feels as expected and accepted (Bergen & Labonté, 2020). The aim with this method was to highlight the elements of the course that pre-service teachers themselves perceived as important and relevant for their professional development without providing any guiding structures.

As the qualitative data from the two open questions served as the main data, we also used four Likert type statements (Table 3) targeting respondents' experiences concerning the technologies used during the course. The aim of these statements was to see how the course design; the authentic integration of different technologies was perceived by the pre-service teachers. Four statements used aligned with TPACK framework, focusing on technology used from the perspective of teaching and learning biology.

3.1 Data analysis

The qualitative research data were analyzed using qualitative content analysis (Elo & Kyngäs, 2008; Hsieh & Shannon, 2005). According to Hsieh and Shannon (2005,

Table 3 Code book

Categories	Definitions	Example responses
PCK Inquiry learning	Perspectives for studying the contents of biology with inquiry learning.	*Inquiry and practical experiments because they make teaching more interesting than studying from the books.*
PCK Authentic environments and materials	Perspectives of using authentic learning environments and materials as part of the inquiry learning process.	*Getting to know the plants would be done using authentic plants and making preparations*
TCK	Focusing on technologies used within the discipline of biology.	*I would make use of microscopes because they can be used to concretize the structure of a cells.*
CK Biology	Focusing on contents of biology.	*Increasing my own understanding of the topics taught (different species and biodiversity)*
PCK Differentiation and characteristics of the students	Targets the characteristics of students that need to be considered when using inquiry learning for biology.	*For example, egg preparation would be quite easy to use in grades 3–6.*
CK Methods	Focusing on research methods used within the biology discipline.	*I also learned knowledge and skills about how to conduct research, the design, and the supplies and time it required.*
PCK Collaboration	Targets the role of collaboration during the inquiry learning.	*I would use working in groups so that students could take notes themselves and make use of their skills and background.*
TPK	Focusing on aspects of using technology to support pedagogical aims.	*SharePoint platform was good, it was open to everyone, and everyone was able to make changes*

p. 1278), qualitative content analysis is a research method "for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns". Elo and Kyngäs (2008) suggested two main approaches for qualitative content analysis—deductive and inductive. The difference between these approaches is based on the availability and use of previous research and previous models to analyze data. The inductive approach is understood as an approach where analyzing and building categories is based on the data; the deductive approach is based on earlier theories and models about the topic (Elo & Kyngäs, 2008). Within this study, we used the deductive approach for analyzing the pre-service teachers' responses related to the biology course (i.e., the TPACK framework was used as the framework for building the final categories). The pre-service teachers' responses to the two questions were combined. During the analysis the responses were reviewed from the perspective of TPACK as manifestations of different TPACK areas. The aim was to obtain the overall picture of the TPACK areas gained, how balanced is the picture is between various TPACK areas.

The data were analyzed using Atlas.ti version 9. The first step of the analysis was to code the relevant aspects from the pre-service teachers' responses related to the TPACK areas. This phase was conducted without strict guidelines, rather by pointing out meaningful aspects that were informative to the topic. In the second phase, the first-level codes were combined for higher-level categories that aligned with the TPACK areas. This phase resulted in eight categories outlined in the code book (Table 3). Within these categories, four categories targeted the PCK and two CK. The TPK and TCK dealt only within one category. This is because the number of responses categorized as PCK was highest and within these responses the PCK was considered from different perspectives. All the areas of TPACK are not mentioned within the code book because these areas were not mentioned in pre-service teachers' responses. Code book contains the TPACK areas that were raised by the respondents. Within the previous TPACK studies the TPACK framework has proven a challenging entity. There have been differences among the definitions of the TPACK areas and difficulties in drawing clear boundaries between TPACK areas (Graham, 2011). These characteristics demand special attention for researchers when using the TPACK as a framework for analyzing the data. Within this study, the challenges with the boundaries between TPACK areas were noticed. The distinctions between areas such as PK and PCK or TK, TPK demanded well acknowledged decisions. The context of the study, the biology course, and the questions asked from pre-service teachers, provided data in where, for example the separation of distinct PK and PCK categories would have been rather vague, two separate categories would not have provided any added any value for the results. Similarly, within TK the responses were combined even with the pedagogical aspect or the content aspects. Because of this, we did not use a separate TK category but TPK and TCK in order to highlight the details of the results. The analysis was conducted by three of the authors. The first step was collaboratively conducted by two researchers, creating the first draft of the code book. This phase resulted in numerous separate codes, with low abstraction level, remaining close to the original materials (Lindgren et al., 2020). The second phase, gaining higher abstraction level by creating the final categories, was conducted by the third author. The final categories and their meanings were discussed with all three authors participating in the analysis. Altogether the final eight categories covers the PCK, TCK, CK and TPK areas.

The analysis continued by counting the frequency of the categories in order to highlight the emphasis of the different TPACK areas. To deepen insight into the relationships of the categories, the code co-occurrence method provided by Atlas.ti was used (Friese, 2019). This method was used to study the relationship between two codes. The coefficient value varies between zero and one (i.e., zero indicates that codes do not co-occur, and one indicates that the two codes co-occur every time they are used). In this case, one indicates how actively the two codes were mentioned together within the same response. The value is counted using the following equation: $c = n1 / (n2 + n3 - n1)$, where n1 equals the number of co-occurrences for codes n2 and n3. Results are provided in a co-occurrence table (Table 4) where the selected codes can be viewed in pairs.

In order to show how successfully the pre-service teachers perceived the authentic integration of technologies the descriptive statistics, i.e., mean values and standard deviations were used. Also, we calculated the *Experiences together scale* i.e., a sum variable of the four separate statements with Alpha value, in order to show uniformity of separate statements. With these approaches the aim was to gain a *justification* for the course design, providing background for the qualitative data, investigating how relevant pre-service teachers perceived the different TPACK areas during course, spontaneously without directly asking.

4 Results

The pre-service teachers' experiences of the technology used during the course were positive from the perspectives of the biology content and teaching biology (Table 4). On the scale from one to six, the mean values were all rather high, above four, indicating positive experiences of studying with the technology during the course. The Alpha value of the sum variable *Experiences together* (0.87) indicating alignment between measured responses.

Table 4 Experiences of technologies used

Technology used in the course:	Mean	SD
…substantially increased my understanding of the technologies suitable for teaching biology.	4.38	1.03
…substantially increased my understanding of teaching biology.	4.24	0.95
…were very well suited for dealing with and learning about the phenomena and contents of biology.	4.49	0.91
…were very suitable for dealing with the topic (cf. NOS, curriculum).	4.52	0.91
Experiences together scale	4.41	0.81

6-point Likert-type scale (1 = strongly disagree, 6 = strongly agree). Experiences together scale is the sum average of four items, Alpha = 0.867

The analysis of the qualitative data produced eight categories covering the areas of PCK, CK, TCK, and TPACK. The biggest area was PCK, which covered the pedagogical areas used within the course. Responses contained comments related to PK and TPK, but within the context of the biology course, these responses reflected the biology content, so they were combined with PCK and TPACK. Responses to the first question, the three most important things that you gained from the course, were typically in the form of:

> "I gained confidence in studying biology, using equipment like a microscope", and "I learned different teaching methods that can be used to teach biology", and "I was reminded of the versatility of approaches to implement teaching of biology. By doing different experiments, students are able observe things, making them easier them to understand the contents".

For the second question, the responses were typically similar to:

> "In my future work, I would use authentic material as, much as possible", and, "If possible, I would like to use microscopes in my future work", and, "The way of studying the plants was very pleasant experience for me and I could use it with my future students".

The results show concrete examples and experiences that appeared meaningful to participants—what they perceived to be the most important elements of the course and what would be suitable for their future work.

4.1 TPACK areas gained from the course

This section first outlines the pre-service teachers' responses to both questions from the TPACK perspective. After this, the frequencies of the categories are described, along with the co-occurrence of the categories.

4.1.1 PCK: Inquiry learning

The biggest TPACK area was PCK, and the biggest PCK subcategory area was *inquiry learning* with explorative methods. These descriptions outlined the pre-service teachers' experiences of the laboratory experiments (see Table 1), where they conducted experiments to study the characteristics of different entities like cell structure and the structure of a flower, fish, etc. The main benefits of the method are that it is a way to concretize biology content and make the content more concrete, visible, and easier for students to understand. Inquiry learning was seen as a way to combine theoretical knowledge with practice. As part of this approach, the role of different instructions became evident. The pre-service teachers indicated that the guidelines, support, and instructions were vital for conducting the inquiry, especially when they reflected on elementary-level teaching.

> "Responses typically indicated the inquiry thing as a useful way for learning the topic, they understood its pedagogical value".

> "[W]e got to try opening a fish, for example, and through this get acquainted with biology. The concrete activities were inspiring, and I would also like to give students similar assignments as a future teacher".
> "Plant preparation illustrates well the structure of the plant and gives a clearer picture of the functions of the plant compared to the pictures and descriptions in the books".

4.1.2 PCK: Collaboration

The PCK subscale *collaboration* emphasized the collaborative nature of learning as an aspect of *inquiry learning*. Collaborating, working, and learning in small groups were experienced as well suited for conducting experiments and for the nature trail walk in the forest. Pre-service teachers experienced collaboration as a way to support their learning via shared expertise and support from their peers, who encouraged them to pose questions and bring up themes and topics that were challenging for them. These activities were understood as important for conducting inquiry learning, creating new ideas, and understanding the phenomena studied.

> "The best ideas and insights come together, and no one is left alone to wrestle with the problems they face".
> "I would also use the collaborative activities and walking in nature in studying biology, because based on the discussions in the group, one can expand his/her own knowledge and ask additional questions".

4.1.3 PCK: Authentic environments and materials

The third PCK subscale, *authentic learning environments and materials*, emphasized the importance of authentic materials and environments as part of inquiry learning. Pre-service teachers reported the nature trail as a positive experience for observing biology content in its natural environments and deepening their understanding. Similarly, the authentic materials added interest and motivation for the topic and enhanced their understanding of the value of nature. Experiments with authentic materials and the nature trail were seen as ways to combine the content from lectures with personal and meaningful learning experiences with nature and learning about biology.

> "In the teaching and inquiry processes, it is good to use real plants instead of a picture, for example. It is worth exploring the nearby environment together with the students."
> "I would use as much authentic materials as possible (e.g., in the preparation of fish). Students would get the most accurate understanding of the topics. The studied themes would be remembered better if they were concretely touched and studied, as opposed to looking at pictures in a book."
> "The last nature task where we walked to the bird tower was inspiring and we got to see and reflect on the diversity of nature."

4.1.4 PCK: Differentiation and characteristics of students

The last PCK subscale, *differentiation and characteristics of the students*, focused on the importance of considering the characteristics of different students in the context of inquiry learning. This area considered the importance of activities for bringing up students' preconceptions of a topic and considered these to be part of the learning activities. Along with pre-knowledge, the ages of the students necessitated some adjustments. Pre-service teachers reflected on the possibilities for inquiry learning during the elementary level, typically finding methods suitable for grades 5 to 6 (ages 11 to 12). Respondents outlined insights into areas that need to be considered when conducting a course using inquiry approaches. The results show the need for scheduling enough time to conduct inquiry practices and build support activities that different pupils may need. In addition, the characteristics of the different students were considered, including the possible special needs of the students. Pre-service teachers indicated the need for special support for students with learning difficulties to help all students participate in various learning activities.

> "With 3rd to 6th classes I would not necessarily use any sharp tools such as knives".
> "I would probably use some assignment related to the pre-knowledge of the students. when you make the pre-knowledge visible, it is easier for you to notice all the things that you have learned
> "…how we are able to support students' learning when he/she has learning difficulties or other healt-related difficulties with learning."

4.1.5 CK biology

The first CK subcategory, *content knowledge biology*, targeted comments reflecting the contents of biology (i.e., biological structures, classification of species, parts of a plant and animal cell), recalling topics that had been learned during basic education and general upper secondary education. Also, the responses contained phrases that could be seen as changes in attitudes. Within these responses, the pre-service teachers indicated a better understanding of the value and importance of nature and a healthy environment.

> "... information about plants, the structure of plants, and photosynthesis. Information about cells, cell parts, and ways they can be studied…"

4.1.6 CK methods

The second CK subcategory targeted the research methods used within the biology discipline. These results showed that pre-service teachers gained an understanding of how research activities in a laboratory setting are conducted and how research activities within the field of biology are designed and conducted. Preparing microscopic samples in the laboratory and studying the structures of plants and cells were especially important.

> "Working with the microscopes in order to study the structures of the fish and eggs."
> "For me, it was important to gain knowledge about how to organize different experimental activities during classes, for example using microscopes and study the structures of a fish."

4.1.7 TCK

Responses related to TCK are closely connected with the CK methods subcategory, the research methods used within biology. These responses were typically rather short, indicating that participants learned how to use different tools and technologies that are typically used within laboratory contexts. The most often mentioned item was the electronic microscopes used for studying the cell structures. Also, other equipment used in the laboratory setting was mentioned within the context of making different experiments.

> "I would use the laboratory tools and microscopes."
> "I would use different research tools as part of the experimental working."

4.1.8 TPK

Like PCK, the areas related to technology were combined with the content of the course, indicating that areas related to technology were all presented as part of the TPK. Altogether, the responses related to TPACK played a minor role. Most of the responses were at a rather general level (i.e., comments that the technologies used were suitable for the purposes used). More focused responses related to the use of cloud services. Respondents indicated that the shared cloud services worked well within the context of this course as a platform for sharing the materials produced in the experiments. The other TPACK area was related to mobile devices, especially their use during the field trip. Mobile technologies, with GPS, worked well to provide information and tasks within certain authentic settings in the forest.

> "I would also use technology in teaching, for example taking pictures and perhaps through some platforms where students would be able to add their outputs made during lessons."
> "I would use a smartphone to navigate during the field trip or while doing tasks. Using smartphones is sure to increase children's interest and make assignments easier to conduct."

4.2 Frequencies and co-occurrence

The frequency of responses shows that the PCK area was highly emphasized; altogether, the four PCK categories garnered 483 mentions (Table 5). Of the PCK categories, *inquiry learning* was the one most often mentioned for both questions,

Table 5 Number of category mentions

Categories	What did you gain from this course?	What would you use for teaching?	Total
PCK Inquiry learning	129	112	241
PCK Authentic environments and materials	35	108	143
TCK	27	57	84
CK Biology	51	9	60
PCK Differentiation and characteristics of the students	39	17	56
CK Methods	40	5	45
PCK Collaboration	15	28	43
TPACK	8	29	37
Total	344	365	709

altogether garnering 241 mentions. In addition, the category *authentic environments and materials* showed well, especially for question two, indicating what respondents would take to their future work as a teacher. The other TPACK areas garnered fewer mentions. The two CK categories garnered 105 mentions, mainly as responses to the first question about what the participants had learned. Areas related to TK were not mentioned very often. The TCK category, as a response to question two, garnered responses indicating that the discipline-specific technologies used within the course could be something they use when working at elementary-level schools.

When studying how the categories relate to each other we can see again the central role of *inquiry learning*. Within the co-occurrence table (Table 6), *inquiry learning* is the core category most connected to all categories, especially *authentic environments and materials* (93 respondents) and *TCK* (70 respondents); these categories were typically mentioned. The results show that *inquiry learning* is the main area that pre-service teachers have gained and extended with other areas. The other areas seem more separated; typically, the number of co-occurrence cases remains below 20.

Table 6 Co-occurrence table

	PCK Auth	PCK Diff	PCK Inquiry	PCK Coll	CK Bio	CK Meth	TCK
PCK Auth	0 (0.00)						
PCK Diff	16 (0.09)	0 (0.00)					
PCK Inquiry	93 (0.32)	36 (0.14)	0 (0.00)				
PCK Coll	19 (0.11)	8 (0.09)	32 (0.13)	0 (0.00)			
CK Biol	12 (0.06)	19 (0.20)	41 (0.16)	2 (0.02)	0 (0.00)		
CK Meth	11 (0.06)	10 (0.11)	44 (0.18)	3 (0.04)	15 (0.17)	0 (0.00)	
TCK	34 (0.18)	8 (0.06)	70 (0.27)	8 (0.07)	12 (0.09)	20 (0.18)	0 (0.00)
TPK	27 (0.18)	4 (0.04)	26 (0.10)	8 (0.11)	3 (0.03)	2 (0.03)	9 (0.08)

5 Discussion

This research continued the tradition of TPACK studies aimed at better understanding the development of pre-service teachers' TPACK. Instead of specially designed intervention the study targeted one of the teacher training courses, focusing on the contents and pedagogical practices of teaching biology. The results indicate that the course design, form the perspective of technology, was perceived as suitable for the course aims. Still, when studying the relevant TPACK areas gained from the course, the role of PCK was highly emphasized. The four PCK subcategories garnered more than twice the number of mentions compared to the other categories. In addition, the responses were typically longer and more detailed than comments related to TPK or TCK. These results align well with previous studies highlighting the role of pedagogical thinking within pre-service teachers' development of TPACK (Valtonen et al., 2019). Elements of the course related to pedagogical aspects most actively triggered pre-service teachers' attention. Still, differing from previous studies is the role of TCK, which was well noticed (Chai et al., 2010; Schmid et al., 2020a, b). We assume that the reason for this is the important and concrete role of laboratory equipment, such as digital microscopes, which were actively used as part of pre-service teachers' laboratory work. These technologies were central to the implementation of inquiry learning.

Compared to the PCK areas, the role of TPK remained low. When designing the course, the aim was to integrate different technologies in pedagogically sound ways to provide pre-service teachers with authentic learning experiences with technology (Gill & Dalgarno, 2017; Tondeur et al., 2012; Valtonen et al., 2015). Technologies with different purposes were integrated, such as cloud services and online mind maps, as shared working environments, and mobile technologies with GPS to provide additional activities for the field trip. We assume that the reason for this modest result is that these technologies were more or less everyday technologies, familiar from participants' normal lives and other teacher training courses. These technologies did not trigger attention or a great wow effect. Phillips and Harris (2018) indicated that we should talk about TPACK within the context of emerging new technologies instead of transparent technologies that have become routine or part of teachers' PCK. Our results may indicate similar phenomena: the technologies for supporting learning, such as cloud services and mobile technologies, were probably transparent for the pre-service teachers. Instead, the digital microscopes were not and showed well on the results. This poses a challenge for teacher training. For pre-service teachers, certain technologies may be transparent; still, the question remains—How able pre-service teachers are to use technology from the perspective of the teachers, to design and maintain different technological environments during a course for supporting students' learning?

From the perspective of TPACK, it seems that the pedagogical components, especially PCK, created the core, or the eyeglasses through which the pre-service teachers perceived the course and collected building blocks for their TPACK. This result is very understandable within the course like this. Still, our expectation was more balanced coverage of all the TPACK areas. From the perspective of developing TPACK, we see these results as important. Authentic experiences of learning with technology have been indicated as one of the key elements for supporting the development of pre-service teachers' readiness to use technology (Banas & York, 2014; Gill & Dalgarno, 2017; Tondeur et al., 2012). This study showed that within this kind of teacher training course, which was designed to provide authentic experiences of learning with technology, the amount of technology taken into account by pre-service teachers is rather small. Still, courses similar to the one targeted in this study are common, covering a large portion of all teacher training studies. According to Phillips and Harris (2018), transparent technologies, as part of PCK but not TPACK, refer to teachers' professional development; transparent technologies have become part of professional teachers' everyday routines. Within teacher training, this PCK and TPACK perspective is more challenging, posing questions about the adequacy of pre-service teachers' abilities to use transparent technologies from the perspective of a teacher, focusing attention again on TPACK. We suggest that focusing on TPACK is important for defining ways to help pre-service teachers better acknowledge the roles of technology, especially from the perspective of teachers. For this purpose, we see the role of the SQD, and especially the design strategy, as important for triggering pre-service teachers' attention to the possibilities of technology. During this course, the design activities remained in a minor role. Along with designing ICT-enhanced materials (Tondeur et al., 2012), we should pay attention to designing and working with different environments and platforms that are used within courses to support different learning practices. The aim should be to pinpoint the roles of technology, even transparent technologies, and how they are designed as technologies for learning.

This study provided us with insight into the content that pre-service teachers gain from a teacher training course designed in pedagogically sound ways, taking advantage of suitable technologies. This study has some limitations. First, it was conducted in Finland as a case study using a qualitative method; these features pose challenges for generalizing the results. Still, we assume that this study, with a rather large target group and qualitative methods, increases the trustworthiness of the findings and makes the results important, providing perspectives that can and should be acknowledged as part of the research field targeting educational technology and teacher training, especially the development of pre-service teachers' TPACK. In addition, we assume that instead of quantitative instruments that directs the attention of respondents to all seven TPACK areas, we were able to better highlight pre-service teachers' real personal experiences and opinions. This approach provided a way to pinpoint the areas of TPACK that pre-service teachers find relevant. In the future, we feel it is important to continue similar studies, but with larger samples and several courses, to gain more reliable results. In addition, the use of different design activities aligning with the SQD framework will be important along with other scaffolds for directing pre-service teachers' attention toward the characteristics and possibilities of the technologies used.

6 Conclusion

This study provides new insight into the development of pre-service teachers' TPACK. The results show the important role of PCK as the core area that respondents gained from a teacher training biology course based on inquiry learning supported with various technologies. The target course can be seen as a one of the many teacher training courses that is not specially designed for targeting mere educational technology, one of the courses that covers a large area of teacher training. The results showed that to support the development of pre-service teachers' more balanced TPACK, it is important to make the role of technology a more explicit target for learning within the context of biology and inquiry learning. It is important to help pre-service teachers to consider better also the roles of the pedagogical technology, along with content specific technologies.

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Data availability The qualitative datasets generated during the current study are not publicly available due to permissions gained from the target group i.e., open data consent was not requested.

Declarations

Conflict of interest The authors have no conflicts of interest to declare, there is no financial interest to report.

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