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SINI KONTKANEN

**STARTING POINTS OF PRE-SERVICE TEACHERS'
TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE
(TPACK) – INTRODUCING A PROTO-TPACK MODEL**

STARTING POINTS OF PRE-SERVICE
TEACHERS' TECHNOLOGICAL
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ABSTRACT

This dissertation focuses on pre-service teachers and upper secondary school students as users of Information and communication technologies (ICT) in education from the point of view of the Technological Pedagogical Content Knowledge (TPACK) framework. While the surrounding world and changing school environment requires teachers in training to use ICT meaningfully in their teaching, there is a need to discover how pre-service teachers develop their abilities and knowledge about integrating technology into their studies. The TPACK framework is a widely used theoretical perspective for investigating teachers' professional knowledge about ICT use in educational settings. TPACK is an important area of research, because until now there has not been a straightforward way to develop teachers' TPACK in practice. Hence, the aim of this dissertation is to provide insights into the starting points of pre-service teachers' TPACK, its development and factors influencing its development.

The empirical research in this dissertation consists of three studies undertaken between the years 2010 and 2016, and published in international research journals. The first two surveys concentrate especially on prior experiences, skills and knowledge of ICT use in education, i.e. the foundation for building up TPACK. In Study I, pre-service teachers (n= 146) were asked to reveal their perceptions of ICT use in education through open-ended questions. Study II explored third-year, upper secondary school students' (n= 84) perceptions of how they see the use of iPads for teaching and learning based on their three years of experience. The target group, third-year upper secondary school students, was chosen in order to find out what kind of skills and readiness we can expect from pre-service teachers entering teacher training, while it has been reported that school experiences strongly affect pre-service teachers' beliefs and assumptions about teaching and learning. This was done by collecting empathy-based stories from students and analysing reflective group discussions. The third study discusses experiences of ICT use in teacher education, i.e. the foundation for the development of TPACK in teacher education. Study III, concentrated on pre-service teachers' (n= 20) experiences of a Second Life experiment during their sex education course as part of their teacher education. The data consist of pre-service teachers' empathy-based stories and reflective group discussions. All the data in these studies were analysed using qualitative methods. In Studies I and III, the data was analysed using qualitative theory-guided content analysis where the TPACK framework was the guiding theory. In Study I, also some quantitative methods with descriptive statistics were used. In Study II, qualitative thematic analysis was used.

Results in this dissertation reveal an unsure foundation on which pre-service teachers start to build their TPACK. This implies they have limited scope to realise different technological possibilities and especially a lack of innovative views of technology use in education. There is a general preference for teacher-centred pedagogy, and few ideas about connecting technology, pedagogy and especially content. There is also variation among pre-service teachers' knowledge in different TPACK constructs. Whereas the results reveal challenges in developing TPACK, they also show that students have a readiness to use ICT in education, and some ideas which can be turned into useful skills. Students' learning experiences, and modelling of pedagogically justified ICT use, are important means to this end.

To help pre-service teachers in becoming proficient in connecting technology, pedagogy and content in their teaching, there is a need for a consistent and coordinated model in teacher education. Therefore, results in this dissertation encourage the suggestion that pre-service teachers should be evaluated through a 'proto-TPACK framework', which takes earlier experiences of technology, pedagogy and content into consideration, as the basis for professional development towards a more mature TPACK. This dissertation presents ideas for developing teacher education using the proto-TPACK framework based on results from earlier studies as well as results from the three studies in the dissertation.

Keywords: *Pre-service teachers, TPACK, ICT*

Kontkanen, Sini

Opettajaopiskelijoiden teknologispedagogisen sisältötiedon (TPACK) tarkastelu proto-TPACK -mallin avulla.

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TIIVISTELMÄ

Tässä väitöskirjassa tarkastellaan opettaja- ja lukio-opiskelijoita tieto- ja viestintäteknologian (TVT) käyttäjinä opetuksessa ja oppimisessa teknologispedagogisen sisältötiedon (TPACK) mallin näkökulmasta. Ympäröivä maailma ja muuttuva kouluympäristö vaativat tulevia opettajia käyttämään TVT:aa mielekkäästi opetuksessaan, joten on tärkeää tarkastella kuinka opettajaopiskelijoiden taidot ja tietämys teknologian integroimisesta kehittyvät opintojen aikana. TPACK:a on käytetty paljon opettajien teknologian opetuskäyttöön liittyvän ammatillisen tiedon tarkasteluun. Aikaisemman tutkimuksen perusteella ei ole voitu osoittaa yksiselitteistä tapaa kehittää opettajien TPACK:a, joten TPACK:n kehittymisen tutkiminen on tärkeä tutkimusalue. Tästä syystä tämän väitöskirjatutkimuksen tarkoitus on tarjota näkökulmia opettajaopiskelijoiden TPACK:n kehittämiseen; sen lähtökohtiin ja siihen vaikuttaviin tekijöihin.

Tämän väitöskirjan empiirinen osa koostuu kolmesta osatutkimuksesta vuosilta 2010–2016. Nämä osatutkimukset on julkaistu kansainvälisissä tutkimuslehdissä. Ensimmäiset kaksi osatutkimusta keskittyvät erityisesti opiskelijoiden aikaisempiin kokemuksiin, taitoihin ja tietoihin teknologian opetuskäytöstä eli TPACK:n kehittämisen perustaan. Ensimmäisessä osatutkimuksessa opettajaopiskelijat (n=146) avasivat käsityksiään TVT:n opetuskäytöstä vastaamalla avoimiin kysymyksiin kyselylomakkeella. Toinen osatutkimus tarkasteli kolmannen vuoden lukio-opiskelijoiden (n=84) mielipiteitä taulutietokoneiden koulukäytöstä kolmen vuoden iPad opintojen perusteella. Lukio-opiskelijat olivat tutkimuksen kohteena, jotta saisimme selville millaisia taitoja ja valmiuksia voimme odottaa opettajankoulutuksen aloittavilta opiskelijoilta. Koulukokemuksien on aiemmin raportoitu vaikuttavan vahvasti opettajaopiskelijoiden käsityksiin oppimisesta ja opettamisesta. Aineisto kerättiin opiskelijoilta eläytymismenetelmällä ja reflektoivilla ryhmäkeskusteluilla. Kolmas osatutkimus tarkasteli opiskelijoiden kokemuksia opettajankoulutuksessa, eli TPACK:n kehittämistä opettajankoulutuksessa. Tutkimus keskittyi opettajaopiskelijoiden (n=20) kokemuksiin Second Life kokeilusta seksuaalikasvatuksen opintojaksolla. Aineisto koostui opettajaopiskelijoiden eläytymistarinoista ja reflektoivista ryhmäkeskusteluista. Kaikki tämän väitöskirjan aineistot analysoitiin laadullisilla menetelmillä. Osatutkimuksissa I ja III aineisto analysoitiin laadullisella teoriaohjaavalla sisällönanalyysillä, jossa ohjaavana kehikkona oli TPACK. Osatutkimuksessa I käytettiin myös kuvailevia tilastollisia menetelmiä. Osatutkimuksessa II laadullinen aineisto analysoitiin teemoittelemalla.

Tämän väitöskirjatutkimuksen tulokset osoittavat, että pohja, jolle opettajaopiskelijat ryhtyvät kehittämään TPACK:aan on melko heikko. Tämä tarkoittaa erityisesti

innovatiivisten ideoiden puutetta teknologian opetuskäytössä, opettajajohtaisen pedagogian suosimista, harvoja sisältöön liittyviä mainintoja sekä vaikeutta yhdistää teknologiaa, pedagogiaa ja erityisesti oppiaineisiin liittyvää sisältötietoa toisiinsa. Lisäksi opiskelijoiden tiedoissa TPACK:n tiedonalueilla on vaihtelevuutta. Tulokset paljastavat haasteita, mutta opiskelijoilla on myös valmiuksia ja kehityskelpoisia ideoita, joita on mahdollista kehittää ja muokata tarpeellisiksi taidoiksi. Tutkimuksen perusteella näyttäisi, että kokemukset esimerkillisen TVT:n käytön mallintamisesta ja pedagogisesti perustellun TVT:n käytöstä ovat tehokkaita keinoja taitojen kehittämisessä.

Jotta opettajaopiskelijoista kehittyisi taitavia osaajia teknologian, pedagogian ja sisällön yhdistämisessä omassa opettajan työssään, tarvittaisiin johdonmukaista ja koordinoitua mallia näiden taitojen kehittämiseen opettajankoulutuksessa. Tästä syystä tämän väitöskirjan tulokset rohkaisivat ehdottamaan, että opettajaopiskelijoita tulisi tarkastella tässä tutkimuksessa kehitetyn proto-TPACK mallin avulla, joka ottaa opiskelijan aiemmat kokemukset teknologiasta, pedagogiasta ja sisällöstä vahvasti esille ja pohjaksi, kun tarkastellaan opettajaopiskelijoiden TPACK:n kehittymistä. Väitöskirjassa esitetään myös ideoita opettajankoulutuksen kehittämiseen proto-TPACK mallin avulla perustuen aiempaan tutkimukseen ja tämän väitöskirjan tuloksiin.

Avainsanat: Opettajaopiskelijat, TPACK, TVT

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Outokumpu, May 2018
Sini Kontkanen

LIST OF EMPIRICAL STUDIES

STUDY I

Kontkanen, S., Dillon, P., Valtonen, T., Renkola, S., Vesisenaho, M. & Väisänen, P. (2016). *Pre-service teachers' experiences of ICT in daily life and in educational contexts and their proto-technological pedagogical knowledge*. *Education and Information Technologies*, 21(4), 919-943. <https://doi.org/10.1007/s10639-014-9361-5>

STUDY II

Kontkanen, S., Dillon, P., Valtonen, T., Eronen, L., Koskela, H., & Väisänen, P. (2017). *Students' experiences of learning with iPads in upper secondary school—a base for proto-TPACK*. *Education and Information Technologies*, 22(4), 1299-1326. <https://doi.org/10.1007/s10639-016-9496-7>

STUDY III

Kontkanen, S., Dillon, P., Kärkkäinen, S., Kukkonen, J., Valtonen, T., & Väisänen, P. (2015). *A Second Life experiment in sex education with pre-service teachers and its contribution to the development of their proto-TPACK*. *Journal of Educational Enquiry*, 14(3), 17-36.

The author of this dissertation was the corresponding author for these three studies. The author had significant responsibility in planning, implementing, analysis as well as reporting the results of these three studies.

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1 INTRODUCTION

The skills needed in present-day working life, also called 21st century skills (e.g. Binkley et al., 2012), are changing the role of education and schools. Students as the citizens and workers of the future are required to learn the ways of thinking, working and using the tools that are needed in their working lives. Information and communication technologies (ICTs, the term technology is used also in this dissertation as a synonym) are strongly connected to these skills as environments, as tools and as means for working. Currently, the new curriculum for basic education in Finland is responding to the challenge. The role of ICT is more emphasized compared to earlier curricula. ICT skills or 'ICT competence', is one of the seven cross-curricular, transversal competencies introduced in the curriculum. ICT is there both as a target and as a tool for learning. It is also mentioned that ICT should be an essential part of a rich learning environment, supporting participation and the development of communal skills and students' personal learning paths (Finnish National Board of Education, 2014).

These changes and demands in working life and in the school world create expectations and additionally provide new possibilities for teachers to take advantage of ICT in education in different learning contexts. Recent research (European commission, 2013) shows that in Finland, despite the investment in technology in schools, its full potential is not realised. Compared to other European countries, especially the students' use of ICT for supporting their learning could be improved (European commission, 2013). This places pressure on teacher education to develop pre-service teachers so that they are able, willing and more confident to use ICT in their teaching.

Following Finland's success in PISA research, the high quality of teacher training has been praised around the world (Malinen, Väisänen & Savolainen, 2012). Despite its good reputation, teacher education is facing challenges due to global change. ICT use in teacher education, especially staff development, has been supported by the Ministry of Education and Culture since the middle 90s (Meisalo, Lavonen, Sormunen & Vesisenaho, 2010). However, there are no common procedures among Finnish teacher education units about how ICT skills are taught and what should be taught. Effort put into ICT use in education varies among universities according to abilities of the teaching staff and the available resources and devices. The challenge is that there are still new teachers entering the profession who do not see the value of ICT in education or do not have suitable skills or confidence for using it (Lei, 2009; Meisalo et al., 2010).

Despite the challenges teacher education is facing, there are interesting possibilities for developing a pedagogically meaningful use of ICT in education. Today's pre-service teachers can be seen as members of the so-called Net Generation (Tapscott, 2009) or Digital Natives (Prensky, 2001 a, b). This means they have lived their whole life with access to technology. The Net Generation phenomenon includes the assumption that all its members are technology literate and can use different technologies. However, even though Net Generation students actively use technology during their free time, they do not necessarily see its value for learning (Lei, 2009; Valtonen et al., 2011). Also, there are differences in their abilities in using technology, indicating that the Net Generation students and also pre-service teachers are not one homogenous group based on their ICT skills (So, Choi, Lim & Xiong, 2012). Despite misgivings about 'Net Generation' being a meaningful generalisation (Bennet, Maton & Kervin, 2008;

Kirschner & Merriënboer, 2013), the characteristics associated with it, and therefore with today's pre-service teachers, pose interesting challenges and possibilities for teacher education, i.e. how to educate pre-service teachers to see the possibilities of different technologies and ways of using them for supporting teaching and learning.

In teacher education, one actively used way to investigate teachers' and pre-service teachers' knowledge related to the use of ICT in education is to discover their Technological Pedagogical Content Knowledge (TPACK). The TPACK framework, introduced by Koehler and Mishra (2005) was developed for research into teachers' technology integration. Teachers' technology use in education is viewed there from the TPACK point of view as three foundational knowledge areas: technology, pedagogy and content. The connections and interactions between the foundational areas, referred to as 'intermediate knowledge areas' are: technological pedagogical knowledge, pedagogical content knowledge and technological content knowledge. Connecting all the knowledge areas, i.e. TPACK, can be seen as the knowledge teachers' and pre-service teachers' need for effective technology use in their profession (Koehler & Mishra, 2009). From the perspective of teacher education and ICT integration, the TPACK framework has been extensively utilised. Instead of focusing merely on technology and its characteristics, the TPACK framework also focuses on pre-service teachers' pedagogical knowledge and content knowledge in the different disciplines taught. The development of TPACK is an important area of research; however, the special characteristics of pre-service teachers' developing TPACK needs more emphasis. Pre-service teachers, as novices at using technology in educational settings, have unique challenges in developing TPACK (Koehler, Mishra, Kereluik, Shin & Graham, 2014).

While global change and the changing school environment create pressure for pre-service teachers to use ICT in their teaching, there is a need for more research focusing on how pre-service teachers develop their abilities and knowledge about technology integration during their studies and how this development can be supported. TPACK, as a highly used theoretical model for discovering teachers' professional knowledge about ICT use in educational settings (see Voogt, Fisser, Roblin, Tondeur & Braak, 2013), provides a well-tried framework for studying and supporting this development. Large numbers of studies have been conducted focusing on the use of TPACK in the teacher education context. Despite this, the results provide a rather unstructured picture of development and of the nature of pre-service teachers' TPACK. Therefore, the main aim of this dissertation is to develop a clearer understanding of pre-service teachers' developing TPACK (hence forth this will be called proto-TPACK). The sub-aims are:

- To develop a refined proto-TPACK model
- To propose a proto-TPACK model and associated tool with potential application in preservice teacher education

In order to develop a clearer understanding of pre-service teachers' proto-TPACK, this dissertation consists of three studies, which answer the following research questions:

- What do pre-service teachers' perceptions of ICT use in education reveal about their baseline knowledge of TPACK? (Study I)
- How does a technology rich learning environment during upper secondary school affect pre-service teachers' starting points with TPACK? (Study II)
- What contribution can an authentic learning experience during teacher education make to the development of the pre-service teachers' TPACK? (Study III)

The research strategy of this dissertation is qualitative survey in the first two studies and in the third, a case study. The dissertation is not a follow-up but a cross-sectional study of pre-service teachers' and upper secondary school students' TPACK. The first study investigates pre-service teachers' perceptions of ICT use in education at the starting point of teacher education. The second study examines how upper secondary school students see the possibilities of iPads in education based on three-year experience of using them in their studies. The assumption is that previous experiences of learning and teaching in school, and in this case within a technology rich learning environment, strongly affect the development of pre-service teachers' TPACK (see Wall, 2016). The third study investigates the contributions of a biology course experiment of sex education conducted using a Second Life environment makes to the development of pre-service teachers' TPACK. The aim of this course was to provide an authentic learning experience that combine content, pedagogy and technology in order to support the development of pre-service teachers' TPACK.

The studies were conducted between 2010 and 2016 at the University of Eastern Finland as components of a project called 'ICT as a part of learning environment', which aimed to develop ICT's pedagogical use in teacher education. My task in the project was to develop and test, in cooperation with teacher educators, different pedagogically meaningful ways to use ICT. Study III was conducted as part of one of these experiments. Study I worked as background research for me in the project to get the overall picture of the situation of pre-service teachers' knowledge and skills of ICT during their free time and schooling. Study II was part of a research sub-project '1 to 1 iPads' in the University of Eastern Finland practice school where I worked. It opened up a possibility to investigate how a technology rich environment, where all upper secondary school students had their personal iPads, affected their views on ICT in education. The data consist of answers to open-ended questions, empathy-based stories and reflective group discussions. Analysis of all three articles was done drawing on mainly qualitative methods.

The dissertation is organized into five parts. Part one overviews theories related to technology integration in education and the theoretical framework of TPACK from different perspectives. Part two provides insight into the methods used, i.e. data collection and analysis. The third part first provides a summary of the results of each article and the fourth part brings together the significant findings. Finally, the fifth part discusses the theoretical and practical implications of the study results, the validity of the research, and offers recommendations for future studies.

2 THEORETICAL FRAMEWORK

The TPACK framework has been shown to be an appropriate theoretical framework for investigating pre-service teachers' integration of technology into learning and teaching (e.g. Herring, Koehler, Mishra, Rosenberg & Teske, 2016; Koehler & Mishra, 2008; Koehler et al., 2014; Mouza, 2016; Voogt et al., 2013). Research has shown that the TPACK framework provides valuable insight into the components of integration, and it is a widely used model for investigating teachers' and pre-service teachers' professional knowledge related to ICT for teaching and learning (see Voogt et al., 2013). Before proceeding to examine TPACK in more detail, it is appropriate to review other theoretical frameworks used in studies focusing on (pre-service) teachers' technology integration.

According to Herring et al. (2016), the field of educational technology research has been conceptually fragmented and partly theoretical in nature. This is due to rapid technology development and change. In addition, much research in this field has utilized frameworks from outside educational sciences and teacher education (Herring et al., 2016). In the sections that follow, current and actively used theories relating to technology integration in education are discussed.

2.1 THEORIES RELATED TO TECHNOLOGY INTEGRATION IN EDUCATION

The 'innovation and adaptation' perspective has been one major influence on ICT integration research. This perspective stresses that individual adoption patterns illustrate successful innovation integration (see Straub, 2009). Rogers' (1995) Theory of Diffusion of Innovations (Innovation Diffusion Theory = IDT) is one of the foundational theories for understanding the adoption of innovations, in this case technology in education. According to IDT, there are five characteristics of an innovation that influence its adoption:

- relative advantage i.e. how the innovation is better than similar ideas
- compatibility i.e. similarity and congruency of the innovation with existing ideas
- complexity i.e. how difficult to comprehend the innovation is
- triability i.e. the possibility to experiment with the innovation
- observability i.e. how easily the adopter can see the use of and concrete results of the innovation

According to Sahin (2006), IDT also takes account of the time dimension in adoption and diffusion, i.e. characteristics that lead people to adopt an innovation early versus late. The theory describes five adopter categories ranging from 'innovator's i.e. people who first try the innovation, to 'laggards' i.e. people who are sceptical of change. IDT has been used across disciplines and "it has influenced many other, more recent, theories of adoption and diffusion of innovations" (Sahin, 2006). Sahin (2006) states that IDT is the most appropriate theory for technology integration in higher education and educational environments. Straub (2009) emphasises the flexibility of the theory to fit both formal and informal adoption environments. But Straub (2009) also criticises the theory because it is difficult to adapt for use with individual studies and it does not explain how to facilitate adoption.

In addition to IDT, according to Lin, Tsai, Chai and Lee (2013) technology integration has been studied from more psychological perspectives. The theory of reasoned action (TRA) is a popular model for describing the factors behind human behaviour. TRA is based on two factors: first, attitudes concerning certain behaviour, whether the behaviour is positively or negatively valued. Second, subjective norms i.e. how 'significant others' value certain behaviour (Ajzen & Fishbein, 1980). In the case of ICT use in education, a teacher's positive or negative attitudes towards ICT use in education, and the opinions of significant others i.e. colleagues, friends, etc., affect the teacher's intention to use ICT in education. The Theory of Planned Behaviour (TPB), as an extension of TRA, examines an individual's actions, such as the use of ICT for education, from the point of view of behavioural intentions which are determined by attitudes, subjective norms and perceived behavioural control (Ajzen, 1985). The added element, perceived behavioural control, consists of resources and possibilities for conducting a certain behaviour and also the self-efficacy of the individual concerned, i.e. how the person sees his/her skills and readiness to conduct that behaviour. According to Teo and Tan (2012), the TPB framework is a valid model for studying preservice teachers' intentions to use ICT in education. Although both TRA and TPB are actively used in teacher education (e.g. Teo, 2010; Teo & Lee, 2010; Valtonen, Sointu, Mäkitalo-Siegl & Kukkonen, 2015), they do not acknowledge the influence of other influences on behaviour such as personality or knowledge (e.g. Conner & Armitage, 1998).

In addition to the TPB and TRA theories, one commonly used model describing diffusion and adoption of technology is the Technology Acceptance Model (TAM), where integration is viewed in terms of perceived usefulness and perceived ease of use (Davis, 1989). This means that the adoption of a technology is affected by how potentially useful it is and how easy it is to use. TAM was developed originally to explain technology integration into business and it was first model to include the contribution of psychological factors to technology acceptance (Teo 2009). Later, the TAM model was used other contexts and according to Teo (2009), it was found to be an appropriate model for education. However, Straub (2009) is critical of TAM because it ignores individual differences and takes for granted the connection between perceived ease of use and self-efficacy. Kreijns, Vermeulen, Kirschner, Buuren and Acker (2013) criticise TAM for ignoring many of the variables which might explain why teachers are not willing to use ICT. Extended models of TAM: TAM2 and 3, added determinants to the perceived usefulness like subjective norm and job relevance (TAM3, c.f. Venkatesh & Bala, 2008) and determinants to perceived ease of use like self-efficacy and computer anxiety (TAM 2, c.f. Venkatesh & Davis, 2000).

These theories and models, and the availability of a variety of others, have meant that it is difficult for researchers to make choices about which ones to use. Therefore, Venkatesh, Morris, Davis and Davis (2003) developed a Unified Theory of Acceptance and Use of Technology (UTAUT). Venkatesh et al. (2003) based UTAUT on a comprehensive review from recent decades where they combined eight different models used for predicting computer use. UTAUT combines the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Planned Behaviour (TBP), Combined TAM and TPB (C- TAM TPB), the Model of PC Utilization (MPCU), Innovation and Diffusion Theory (IDT) and Social Cognitive Theory (SCT). All these models have been used separately in a variety of studies. From these eight models, Venkatesh et al. (2003) synthesized 32 determinants of acceptance giving four constructs for user acceptance and usage behaviour: 'performance expectancy' i.e. how much technology will assist in job duties; 'effort expectancy'

i.e. how easy the technology is to use; 'social influence' i.e. the social pressure to use technology; and 'facilitating conditions' i.e. how much the organisation is supporting the change. Four key factors: gender, age, experience and voluntariness of use, are important moderators of the different constructs.

According to the review by Williams, Rana and Dwivedi (2015), the UTAUT model is actively used in the fields of business, management, information systems and technology. In education its use is limited, and some studies questions its suitability stress and the need for more testing in educational settings (see Phillips, 2014; Straub, 2009).

Overall, the theories and models discussed above are well-known and well-used in the field of the integration of technology into education, but they have limitations. For the most part they were developed in fields other than education and teacher education. Moreover, they examine the phenomenon from perspectives where the psychological factor is dominant, not the overall competence of the teacher. In addition, the previously mentioned models do not take into account pedagogical and content factors. The TPACK framework, on the other hand, was developed especially within the discipline of teacher education and therefore it respects the features of teacher professional development and technology integration (Herring et al., 2016). The TPACK framework provides both a structure to investigate teachers' use of ICT in education and an analytical lens to discover teachers' instructional decisions (Graham, Borup & Smith, 2012). It takes into account the development of teachers' overall competence and three knowledge areas, technology, pedagogy and content. For these reasons, TPACK was chosen as the initial theoretical frame for this dissertation. The extension and refinement of this frame through the research reported here is the major contribution to knowledge made in this dissertation.

In the next sections, the central concepts of the framework, its history and development, research related to its constructs, the development of TPACK especially in teacher education, and its challenges, are introduced.

2.2 TPACK FRAMEWORK

Koehler (2011) describes the TPACK framework as follows:

“TPACK attempts to identify the nature of knowledge required by teachers for technology integration in their teaching, while addressing the complex, multifaceted and situated nature of teacher knowledge. At the heart of the TPACK framework is the complex interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK)” (Koehler, 2011; section 1).

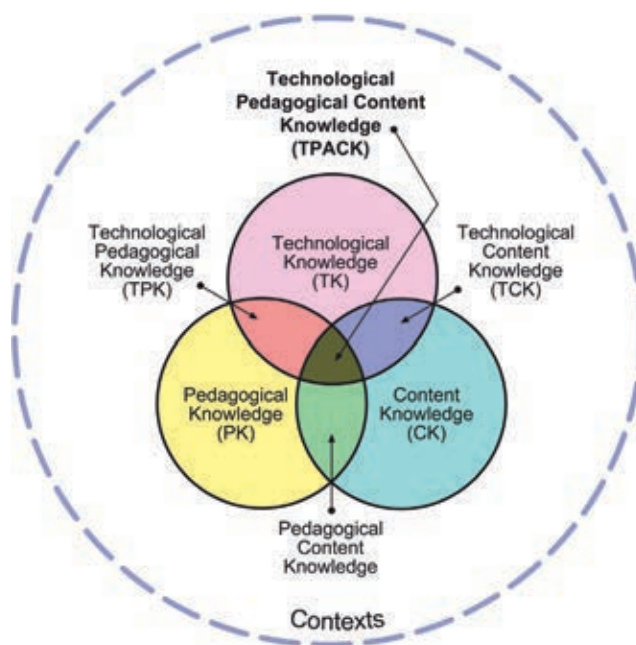


Figure 1. TPACK-framework (Reproduced with permission of the publisher, © 2012 by tpack.org).

The interplay between these three knowledge areas results in four intermediate knowledge areas: Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK) and Technological Pedagogical Content Knowledge (TPACK). The TPACK framework is typically presented as a Venn diagram (Figure 1), where major knowledge areas are the coloured equal-sized circles and the intermediate knowledge areas are presented as the intersections of the circles (see Koehler & Mishra, 2009). Brief descriptions of different knowledge areas are presented in the Table 1.

Table 1. TPACK knowledge areas, acronyms and explanations.

Knowledge area	Acronym	Explanation
Technological knowledge	TK	Knowledge of different ICT's, interest in technology
Pedagogical knowledge	PK	Knowledge of learning, teaching and students/pupils
Content knowledge	CK	Knowledge of subject-matter; concepts, theories
Technological pedagogical knowledge	TPK	Knowledge of ICT use in learning
Technological content knowledge	TCK	Knowledge of ICT use in a certain subject-matter
Pedagogical content knowledge	PCK	Knowledge of learning in certain subject-matter cf. Shulmans' concept of PCK in section 2.3.1
Technological pedagogical content knowledge	TPCK/TPACK	Knowledge of technology integration into learning in a certain subject

Next, the development of the TPACK framework is examined and then its knowledge constructions are discussed in more detail.

2.3 DEVELOPMENT OF THE TPACK FRAMEWORK

2.3.1 Origins in Pedagogical Content Knowledge (PCK)

The TPACK framework builds on the pedagogical content knowledge (PCK) framework of Shulman (1986). Therefore, it is informative to explore PCK before a taking a closer look at the TPACK framework itself. Shulman (1986) introduced the concept of PCK as a means to enriching the practice and research of training and evaluation of pre-service teachers. In his opinion, the ongoing debate about the nature of teaching and teacher education was not paying enough attention to subject matter and its interaction with pedagogy. There was also pressure to clarify the theoretical basis of teaching to counter the then common political perception that teaching could be practiced by anyone (Shulman, 1986). Shulman (1987) states that pedagogical content knowledge is a teachers' own specific form of professional understanding where knowledge of pedagogy and content are connected in a particular way. According to Shulman (1986), PCK consist of knowledge of 1) regularly taught topics in a certain subject area 2) the ways of representing and formulating a certain subject that makes it understandable to others, and 3) the interests and abilities of learners in the topics of a certain subject area.

There has been plenty of research on PCK during the thirty years of its history. According to Cox (2008), Grossman (1990) elaborated Shulman's original concept of PCK with four central components: 1) knowledge and beliefs about the purposes for teaching a subject at different grade levels, 2) knowledge of students' understanding of the subject matter, 3) curricular knowledge, and 4) knowledge of instructional strategies and representations in a subject matter. This is the most widely accepted description of PCK. In their review of PCK in mathematics educational studies, Depaepe, Verschaffel and Kelchtermans (2013) identified eight components of PCK:

- students' (mis)conceptions and difficulties
- instructional strategies and representations
- math tasks and cognitive demands
- educational ends
- curriculum and media
- context knowledge
- content knowledge
- pedagogical knowledge.

Additionally, knowledge of assessment has been considered as a component of PCK in recent years (Cox, 2008).

Since its inception, the concept of PCK has been critiqued, especially the lack of precision in the model. There are difficulties in distinguishing between pedagogical knowledge, content knowledge and pedagogical content knowledge; the boundaries between them are fuzzy. This causes difficulties in measuring them (Cox, 2008). In addition, the question of whether pedagogical content knowledge should be integrative or transformative in nature causes some ambiguity. PCK as an integrative model

does not acknowledge PCK as a domain of knowledge, but sees it as a combination of independent knowledge bases of a subject matter, pedagogy and context. A transformative model on the other hand, sees knowledge bases containing a subject matter, pedagogy and context as a latent resource which transforms into PCK i.e. a synthesised knowledge base for teaching. In addition to these “extremities” in the continuum of the PCK models presented in the research literature, there are some researchers who place themselves between the extremes, i.e. acknowledge both foundational knowledge bases (subject matter, pedagogy and context) and PCK as domains, stressing that changes in one domain does not unavoidably affect the other domains. Theoretically this “in between model” is not as precise and powerful as the two extremes, although through the lenses of the extremes the same teaching might be interpreted differently (Gess-Newsome, 1999). This critique of PCK is similar to the critique confronting the TPACK framework (see chapter 2.6 Challenges and critique with TPACK).

Although PCK has attracted criticism, it has also made important contributions to the research of teaching and teacher knowledge. According to Gess-Newsome (1999), contributions are 1) providing a new analytical framework for research into teacher cognition, 2) stressing subject matter knowledge and its teaching, 3) combining findings from related research, and 4) offering an integrated vision of teacher knowledge and classroom practice.

2.3.2 History of TPACK

In the beginning of the 21st century, the field of educational technology research was fragmented and atheoretical in nature (see Angeli, Valanides, & Christodoulou, 2016). Therefore, the need for a theoretical model for research of technology integration into education became evident. At that time, Shulman’s (1986, 1987) concept of teachers’ pedagogical content knowledge had become “common currency” in teacher education, so it was taken as a basis for many approaches to theoretically understand and explaining a teacher’s special knowledge for using technology in their professional work (Voog et al., 2013).

Pierson (2001) first suggested adding technological knowledge to the concept of pedagogical content knowledge and named the intersection of these knowledge areas ‘technological pedagogical-content knowledge’. In her opinion, this intersection would define the effective integration of technology into teaching. There were also other approaches to extend Shulman’s original PCK framework with technology (e.g. ICT-related PCK by Angeli & Valanides, 2005; TPCK by Koehler & Mishra, 2005; TPCK by Niess, 2005).

According to the Voogt et al.’s. (2013) review of TPACK literature, there are three views of TPACK: TPACK as extended PCK, TPACK as a unique and distinct body of knowledge, and TPACK as the interplay of three knowledge areas and their intersection. The first, TPACK as an extended PCK, emphasises the role of PCK, arguing that technology is already part of that. TPACK is helping to better understand the potential of emergent technologies that are not yet transparent. In this view, TPACK has also an adaptive nature, i.e. when technology becomes transparent in educational practice it becomes part of PCK (Cox & Graham, 2009; Niess, 2005). The second view, TPACK as a unique and distinct body of knowledge, represented especially by Angeli and Valanides (2009), examines TPACK from the transformative view. In that context TPACK is a distinct body of knowledge, which can be developed and assessed on its own. The

third view of TPACK refers to the framework originally presented by Koehler and Mishra (2005). Angeli and Valanides (2009) mentioned that this view of the TPACK framework of Koehler and Mishra (2005) is an integrative view of TPACK where it is developing from the three knowledge areas and their intersection.

After Koehler and Mishra (2005) described the model of technological pedagogical content knowledge (TPACK) and described each of its central constructs, the term TPACK started to “gain popularity”. Already in 2012, Voogt et al. (2013) found 200 references to the TPACK framework in their literature review of the subject. In the literature, TPACK was first called TPCK, but changed in 2007 to the more easily spoken acronym, TPACK (Thompson & Mishra, 2007).

2.4 CONSTRUCTS OF THE TPACK FRAMEWORK

In earlier research on TPACK, definitions of different knowledge constructs of TPACK vary, from very detailed definitions of one area to descriptions remaining mainly on the surface level (see Cox, 2008). The aim of the TPACK framework is not to define the “goal level” for different knowledge areas of TPACK, rather TPACK from (pre-service) teachers’ perspective can be seen as a flexible framework, as a developing and changing knowledge entity constructed by the teacher, an entity that changes and develops based on new experiences, new knowledge and new learning. Still, in order to use the framework efficiently there is a need for common understanding of each TPACK area. For this purpose, the knowledge constructs of TPACK are introduced next based on established research (see Brantley-Dias & Ertmer, 2013; Cox, 2008; Cox & Graham, 2009; Koehler & Mishra, 2005; Koehler & Mishra 2008; Koehler et al., 2014; Voogt et al., 2013). In each of the sections the concept of the ‘knowledge construct’ is first defined and then different approaches to the concept from previous research in pre-service teachers are explored. The aim is to provide an overview of the constantly evolving knowledge areas of pre-service teachers’ TPACK.

2.4.1 Foundational knowledge areas

TK – Technological knowledge

Plainly described, technological knowledge (TK) is teachers’ knowledge about technology. A wider perspective contains knowledge needed to use technology and the ability to solve problems with technology (Voogt et al., 2013). In addition, TK has been defined as (pre-service) teachers’ interest toward technology, interest and willingness to follow the development of new technology. Because technology is such a wide and changing concept, TK can be taken not only as instrumental knowledge but also knowledge of its affordances and constrains of a given technology (Voogt, Fisser, Tondeur & Braak, 2016). Technological knowledge enables a person to accomplish a variety of different tasks using ICT and to develop different ways of accomplishing a given task. Koehler and Mishra (2008) characterise TK also as something always in a state of flux, because technology is changing all the time. Teachers need to develop their skills and knowledge in interaction with technology throughout their professional career, also during their teacher studies. Teachers’ interests in technology, their awareness of different technologies, and the development of their use of technology contribute to the wider view of technological knowledge (Koehler & Mishra, 2008).

Again, in order to define TK, it is important to be clear what is meant by technology. In their original definition of technology in the TPACK framework, Koehler and Mishra (2005) described it both as modern technology such as computers, the Internet, and so forth, as well as more commonplace technologies, such as an overhead projector and blackboard. Later on, they focused on digital technology. Cox and Graham (2009) defined technology as something emergent, i.e. technology which is not yet transparent in context. The definitions of technology in research articles typically contain variations according to the research interests. Typically, in survey studies TK is defined at a very general level referring to computers, mobile phones, Internet, applications, software, altogether the digital technologies used within the education context (see Schmidt et al., 2009; Valtonen et al., 2015). In addition, there are TPACK studies focusing on certain technologies, for example social media (Valtonen, Kontkanen, Dillon, Kukkonen & Väisänen, 2014). The unstable feature of technology, i.e. its rapid and constant change, means that teachers need to be lifelong learners, able to tolerate ambiguity, frustration and change (Koehler & Mishra, 2008).

Research on pre-service teachers' TK offers various commentaries on its quality and value for overall TPACK development. Finger, Jamieson-Proctor and Albion (2010) claim the assumption that preservice teachers' have strongly developed TK needs to be questioned and their knowledge of technology should be audited at an early stage. Developing TK is very important, while according to Özgün-Koca, Meagher and Edwards (2009/2010) lack of TK will apparently affect pre-service teachers' technology use in their future classroom. ICT integration into the courses through observation and participation has a positive impact on pre-service teachers' TK (Polly, Mims, Shepherd & Inan, 2010). Additionally, according to Chai, Koh and Tsai (2010), ICT courses with components that directly instruct the use of technological tools and provide pre-service teachers with experiential learning of pedagogical approaches are effective for raising TK and PK.

PK – Pedagogical knowledge

Pedagogical knowledge (PK) refers to teachers' knowledge of teaching and learning. According to Koehler and Mishra's (2005) original definition, PK is a deep knowledge of practices, processes, strategies, procedures, methods and aims of instruction, assessment and student learning. In 2008, Koehler and Mishra added understanding of cognitive, social and developmental theories into the concept of pedagogical knowledge. However, PK is not described strictly in the TPACK framework. Mishra, Koehler and Henriksen (2010) indicate that the TPACK framework does not provide directives within PK, i.e. it does not specify preferred pedagogical approaches. Similarly, Brantley-Dias and Ertmer (2013) describe TPACK suitable for various pedagogical orientations. This provides again the possibility of tailoring PK and TPACK to different research interests in defining teachers' knowledge of pedagogy.

Despite or because of this freedom/possibility of definition, recent research has tended to describe PK to align with the different theories and frameworks available. Valtonen et al. (2011) used Lahdes's (1997) categorization of basic teaching categories as a way of discovering and categorising pre-service teachers' PK. In addition, pre-service teachers' PK has been outlined using the theory of meaningful learning (see Jonassen, 1995) where pedagogical focus was connected to five dimensions of meaningful learning: active, constructive, authentic, intentional and collaborative (Chai, Koh, Tsai, & Tan, 2011). Lee, Chai and Koh (2012) examined pre-service teachers' TPACK from the studentcentred pedagogy point of view.

Chai et al. (2011) noticed that PK has a major effect on pre-service teachers' TPACK and that increasing it is foundational for TPACK development. In addition, overall TPACK development is connected with pre-service teachers' pedagogical knowledge i.e. the views they have about learning as student-centred or teacher guided actions (Gao, Chee, Wang, Wong & Choy, 2011). Therefore, for example, Chai et al. (2010) and Pamuk (2011) suggest that in terms of TPACK, pre-service teachers should be first introduced to pedagogical knowledge and after that to the remaining knowledge areas and the connections between them.

CK – Content knowledge

Content knowledge (CK) is knowledge about facts, concepts, theories and processes about the subject-matter that is to be learned or taught (Shulman, 1987). According to Koehler and Mishra (2008), CK is very important for teachers in their understanding of the different knowledge constructs and the nature of inquiry in the disciplines they teach. Without teachers' having a sound knowledge base of content, students might receive incorrect information and develop misconceptions, thus complicating their learning and understanding. Koehler and Mishra (2008) also recognise that some CK is contentious and there may be disagreement about its status within a given subject area. They saw it as very important for the overall TPACK that content knowledge is discussed carefully (Koehler & Mishra, 2008). According to Özgün-Koca et al. (2009/2010), CK is a basis for the development of pre-service teachers' PCK.

In the research literature on TPACK, the focus of CK varies from studies where an area of CK is not specified in detail to studies where CK might be something that is subject- or topic-specific, or a form of trans-disciplinary knowledge, like 21st century skills (see Mishra et al., 2010; Valtonen et al., 2015). Voogt et al. (2013), in their review, found it surprising that only a few articles discuss the meaning of TPACK for a specific subject domain and stress this is something that needs to be better understood. According to them, subject-specific research is mainly found in the fields of science, mathematics and social studies. In the fields of language, arts and humanities, TPACK research is not so common (Voogt et al., 2013). Therefore, Angeli et al. (2016) encourage more empirical and qualitative research from the different content domains especially in areas that have not yet been systemically investigated, like the fine arts.

2.4.2 Intermediate knowledge areas

TPK – Technological Pedagogical knowledge

Teacher's technological-pedagogical knowledge (TPK) is knowledge of how technology is able to be used in different pedagogical situations and for students' learning (Koehler & Mishra, 2009). An essential feature of TPK is an interaction between TK and PK (see Cox, 2008; Koehler, Mishra & Cain, 2013). The supportive role of technology for pedagogy, for example fostering collaboration, is also stressed in research (Koehler & Mishra, 2005; Koehler et al., 2014). Because the most popular software programs are not designed for educational purposes, according to Koehler and Mishra (2008), teachers need to be open-minded with technology and have skills to go beyond the technology, i.e. finding ways to use it for their own pedagogical purposes with some understanding of its weaknesses. Ferdig (2006) has made a similar point in the context of supporting teachers with pedagogically meaningful technology. Teachers can also

learn from other teachers who have found meaningful ways to use technologies that are not designed for educational purposes.

In her conceptual analysis of the TPACK framework, Cox (2008) discussed different aspects concerning TPK. First, the role of content is problematic, because teachers' instructions always connect to some subject-matter, i.e. content. This causes problems with distinguishing TPK from TPACK. In addition, the question of the role of instructional strategies connected to TPK is open, i.e. are technologies connected to general pedagogical strategies or to content-specific strategies? Cox (2008) saw TPK as a knowledge of interaction between technology and pedagogy, not necessarily connected to topic- or content-specific instructional strategies. Cox and Graham (2009) conclude that "focus on generic versus content-specific strategies is particularly useful for differentiating between TPK and TPACK".

TCK – Technological Content knowledge

Technological content knowledge (TCK) is a teacher's knowledge of technologies typical and important for a given subject-matter. A teacher knows, for example, different ways of how technology is used to collect data in biology. According to Koehler and Mishra (2008), TCK is an understanding of the influences and constrains between technology and content. Koehler and Mishra (2008) regard TCK as the most neglected aspect of the knowledge areas in the TPACK framework. Cox (2008) listed three issues that are of concern regarding TCK. First, the boundary between TCK and TPACK is unclear when considering TCK in a pedagogical context. Second is whether just listing technologies in a content area comprises TCK. The third issue concerns whether it is even possible to have TCK in an educational context where pedagogy is such a strong component.

PCK – Pedagogical Content knowledge

Pedagogical content knowledge (PCK) as an intermediate knowledge area of the TPACK framework is described in a way similar to Shulman's (1986) concept of it: knowledge of how to teach a certain subject matter. PCK was first introduced in the 1980's and it has been used extensively although there is no universal agreement about how to conceptualise it. Differences relate to the elements connected to PCK and descriptions of these elements. Key characteristics recognised by all researchers of PCK are knowledge of representations of the content, understanding learning difficulties and perceptions of students related to that content, and PCK's deep connection to classroom practice and its gradual development with new experiences (Angeli & Valanides, 2009; Cox, 2008). A more detailed description of PCK is given earlier in Chapter 2.2.1.

2.4.3 Combining the Constructs - TPACK

According to Koehler et al. (2014), TPACK "refers to knowledge about the complex relations among technology, pedagogy, and content that enable teachers to develop appropriate and context-specific teaching strategies." (Koehler et al., 2014, p. 102). TPACK integrates all the knowledge constructs mentioned earlier.

According to Cox's (2008) concept analysis of TPACK, complexity of the construct is the most often mentioned quality of TPACK among 89 different definitions she found from the research literature. The complexity of TPACK means that in order

to understand the framework, not only each of the knowledge areas need to be understood but also the intricacy of the relationship between all the knowledge areas. Part of the complexity of the TPACK framework is that all of the knowledge areas are overlapping (Cox, 2008).

2.5 TPACK AND TEACHER EDUCATION

As Koehler et al. (2014) stated, “[an] important part of the TPACK framework is that TPACK does not exist in a vacuum but rather is grounded and situated in specific contexts”. Therefore, it is important to connect TPACK to the context where it is examined (see surrounding circle in TPACK-figure, Figure 1). As the TPACK framework itself is a quite flexible frame, and does not specify in detail the desired knowledge “level”, descriptions of the context provided next, give some indications of it.

2.5.1 TPACK context in this dissertation

In the case of this dissertation, the context is teacher education in Finland. In Finland, teacher education is located at the universities. Pre-service teachers of class teacher education major in ‘science of education’ or ‘educational psychology’. Pre-service teachers of special education major in ‘special education’. In both cases the obligatory minor is a ‘multidisciplinary study program in basic education’, which provides students with the professional skills they need to master and teach obligatory subjects in comprehensive school grades 1-6. Pre-service teachers of subject teacher education major in some subject(s) of basic education. All pre-service teachers study ‘teacher pedagogical studies’, which gives them right to teach in schools. (Malinen et al., 2012)

From the perspective of the teacher or pre-service teacher, the TPACK framework does not define what the different TPACK areas should contain, nor does it define the kind of knowledge teachers should have. However, there are other sources that may provide interesting perspectives for the ‘content’ of TPACK, especially for the different technologies and pedagogical practices available. The annually published Horizon-reports provide five-year development horizons related to technologies used in K-12 education (see Freeman, Adams Becker, Cummins, Davis and Hall Giesinger, 2017). These horizons provide suggestions for what to expect in the field of developing educational technology and pedagogy, which can be used as perspectives for building (pre-service) teachers’ TPACK. In Finland, a guideline for defining desirable TPACK content can be found in the national curriculum. The role of technology is emphasized as a tool, target and as an environment for learning, but offers relatively general descriptions, where the more detailed technology choices are left open. The prevailing pedagogical approaches to learning in the national curriculum are grounded in constructivist learning theory and collaborative and meaningful learning. (Finnish National Board of Education, 2014). The concept of twenty-first century skills (c.f. Voogt & Roblin, 2012), can also be seen as a guiding perspective, especially for the pedagogical areas. Twenty-first century skills emphasise skills for collaboration, self-directed learning, problem solving and creative and critical thinking. According to Voogt and Roblin (2012), these skills should be considered as learning practices i.e. learn by collaborative practices, problem solving activities and so on. This way the twenty-first century skills can also be seen as content or even targets for (pre-service) teachers’ TPACK.

Next, the constructs of TPACK are opened up specifically from the point of view of teacher education in Finland.

While teachers' TK develops throughout their professional career (Koehler & Mishra, 2005), it is important to start to support the integration of technology in the early phases of teacher education. However, the broadness of the concept of TK makes this challenging. We should ask what are the technologies with which we should familiarise the pre-service teachers, and what are the skills/knowledge we expect them to have mastered during teacher education. As was mentioned earlier, the national curriculum, for example, does not give detailed answers to these questions. Moreover, the scope of TK varies between research contexts. In this dissertation, technology has been defined at different levels: in Study I at the general level of ICT; in Study II as iPads and their applications; and in Study III as the virtual learning environment *Second Life*. This again reinforces the flexible nature of TPACK framework, providing possibilities for different research settings.

In teacher education, developing pre-service teachers' pedagogical knowledge is an implicit part of studies. In Finland, pedagogical studies are a mandatory part of all teacher education programs, (Malinen et al., 2012). Research has described the construction of pedagogical knowledge, or learning to teach, as a constructive process that commences long before an individual begins a teacher education program (c.f. Wall, 2016). According to Bryan (2003), pre-service teachers develop preconceptions based on their earlier experiences through which they view and interpret new knowledge. These beliefs influence their subsequent pedagogical decisions and actions. The preconceptions which are foundational to the beliefs are relatively resistant to change. Therefore, it is important to understand more about the content and source of them (Bryan, 2003; Knowles & Holt-Reynolds, 1991; Levin & He, 2008). A consideration of the role of prior experiences on preservice teachers' pedagogical knowledge has been taken into account in the research frame of this dissertation.

In Finnish teacher education, CK builds on the knowledge pre-service teachers' gain from upper secondary schools. For pre-service teachers of class teacher and special teacher education, the multidisciplinary study program provides the CK of the obligatory subjects, but the emphasis in these studies is mainly on pedagogical approaches to those subjects. In the case of pre-service teachers of subject teacher education, the students gain CK from their subject studies (Malinen et al., 2012). The national curriculum for basic education is organised according to obligatory subjects, but the emphasis is turning to connecting these to real-life themes. The curriculum gives directions to what CK pre-service teachers should master (Finnish National Board of Education, 2014)

While pre-service teachers' pedagogical knowledge is strongly based on their earlier learning experiences in school (see Wall, 2016), a related assumption in this dissertation is that pre-service teachers' TPK is influenced by their experiences of ICT use for learning in school. Reports of ICT use in school contexts suggest there is a large variation in these earlier experiences, and therefore the level of pre-service teachers TPK will be expected to vary widely. A further assumption in this dissertation is that pre-service teachers learn from other teachers, first from their school teachers and later from their educators at the teacher education during courses and practice periods. Therefore, it is important to support pre-service teachers during their studies by modelling pedagogically meaningful ways of using ICT. According to Gao et al. (2011), pre-service teachers are able to apply their TPK in the beginning phase of their practice. However, Henderson, Bellis, Cerovac and Lancaster (2013) and Gill

and Dalgarno (2017) have found that there is great variability in practice experiences especially when it comes to technology integration into education. Therefore, it is important that during teacher education, TPK is gained from technological courses, where technology is viewed from pedagogical perspective, as well as through practice.

As it was mentioned earlier, it is not easy to find TCK in an educational context, while so much influence comes from pedagogy (Cox, 2008). In Finland, it is mainly the subject teachers who get TCK in their subject studies, especially in the fields where technology is vital for the subject. The main emphasis in Finnish class teacher education in their multidisciplinary studies is on PCK, where the pre-service teachers are educated to pedagogically master obligatory subjects in comprehensive school grades 1-6. In subject teacher education the connection between content and pedagogy is gained mainly during their pedagogical studies (Malinen et al., 2012).

2.5.2 Paths to develop TPACK in teacher education

Koehler et al. (2014) point out that the development of TPACK is an important on-going area of research because work so far has not shown a straightforward way to develop teachers' TPACK. Although the TPACK framework was made for, and also used in, teacher training, there is a tension between how it was developed and how different knowledge areas are introduced to pre-service teachers during their studies. Additionally, it is said that there are unique challenges in developing TPACK with pre-service teachers when they begin with "minimal levels of all the TPACK constructs" (Koehler et al., 2014).

Research has shown that integrating TPK, TCK and TPACK into teacher training helps pre-service teachers in moving their identity from learners to teachers and gives them a holistic view of teaching (Özcün-Koca et al., 2009/2010). But Cox (2008) suggests that it is possible that different teacher groups (elementary, secondary, postsecondary) differ in their proficiency with TCK, TPK and TPACK. If this is true, then the paths towards developing TPACK for these groups also differs. The research literature suggests there are indeed different paths for developing TPACK. Three reviews of TPACK research (see Koehler et al., 2014; Mouza, 2016; Voogt et al., 2013), where ways of developing TPACK are discussed extensively, are examined in the next paragraph.

Voogt et al. (2013) took an overview of 55 peer-reviewed journal articles. They found several strategies to support teachers' and pre-service teachers' TPACK development. In their view, one of the most important strategies is technology-enhanced lessons or course design. Additionally, modelling how to teach in a technology-rich environment, and teachers' thinking and context as a starting point for TPACK development are evident in the research literature. From their review of the research, Koehler et al. (2014) identified three different paths for developing TPACK for teachers and pre-service teachers: from PCK to TPACK, from TPK to TPACK and developing PCK and TPACK simultaneously. Mouza (2016) synthesized literature on promising approaches to develop TPACK and suggested three different pathways: the stand-alone educational technology course, instructional strategies embedded within the educational technology course or content-specific methods courses, and TPACK development in the context of teacher education programmes. As a summary and synthesis of Voogt et al. (2013), Koehler et al. (2014) and Mouza (2016), five different pathways for developing TPACK are introduced here (see Figure 2).

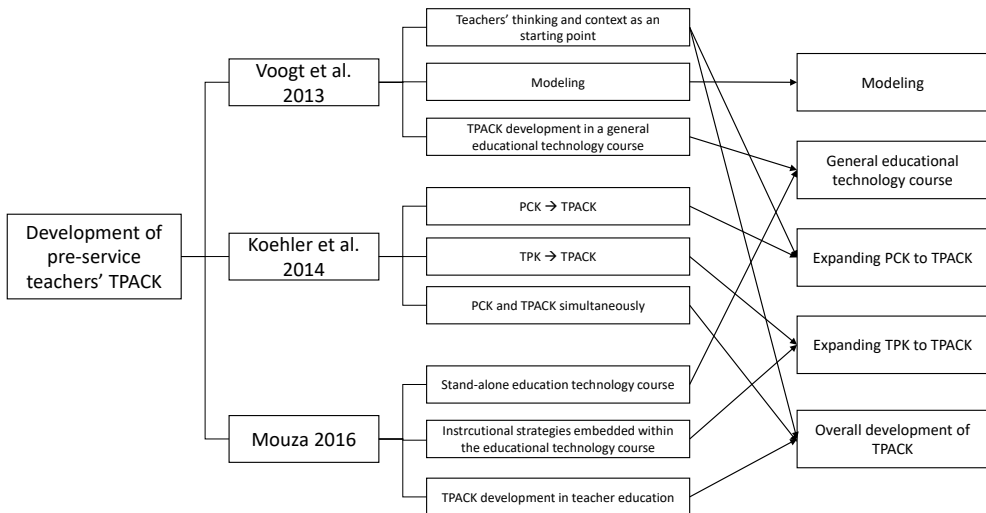


Figure 2. Development of pre-service teachers' TPACK according to Voogt et al. (2013), Koehler et al. (2014) and Mouza (2016).

The first path, 'Modelling', connects pre-service teachers with practicing teachers. According to the review of Voogt et al. (2013), pre-service teachers lack experience in implementing technology-based lessons. They recommend to support this by connecting pre-service teachers with practicing teachers. Also, Özcün-Koca et al. (2009/2010) found that pre-service teachers need to experience exemplary use of advanced technologies in classroom situations to understand the possibilities of technology. Furthermore, their educational experiences as learners and their observations during teacher education (i.e. what they see other teachers and university lecturers doing) affect their planning and assessing of learning activities with and without ICT and the development of their TPK and TPACK skills (Hofer & Harris, 2010; Meagher, Özcün-Koca & Edwards, 2011; Polly et al., 2010; Özcün-Koca et al., 2009/2010). Tondeur et al. (2012) stressed the importance of teacher educators as role models to prepare pre-service teachers for technology use. They also highlight reflecting on attitudes about the role of technology in education, and learning technology by design and collaboration with peers as key themes in preparing pre-service teachers for technology use.

The second path, 'General educational technology course', describes possibly the most common way to develop the TPACK of pre-service teachers, i.e. TPACK development in a stand-alone educational technology course. In such courses, the focus is on learning about technologies and their affordances and constructs in teaching and learning (Mouza, 2016; Voogt et al., 2013). Although, there are several benefits (improved self-efficacy, good overview, strong foundation) of this approach, research has showed that ICT-related courses are not enough to promote TPACK development (Gao et al., 2011; Mouza, 2016). Solving this problem has been attempted in several research and development projects by placing more emphasis on the interconnections between technology, content and pedagogy in course curricula (Mouza, 2016; Voogt et al., 2013).

The third path, 'Expanding PCK to TPACK', is more typical for in-service teachers who first have acquired methods and experiences without the use of technology and later are exposed to how technology might be used with these. It is notable that teachers' prior beliefs might limit their ability and willingness to try new technologies (Koehler et al., 2014). An example of this approach to TPACK development is the use of activity types. Here, a teacher moves from choosing learning goals and practical pedagogical decisions to selecting appropriate activity types, assessment strategies and tools and resources (Harris & Hofer, 2009). In another example of this approach, Niess (2009) discussed the development of teachers' TPACK through five different phases: recognising, accepting, adapting, exploring and advancing. In this model, there is an assumption that PCK exists already and technology is the new aspect.

The fourth path, 'Expanding TPK to TPACK', is typical for many teacher education programmes, where pre-service teachers are first introduced in technology integration courses to the use of technology with general pedagogical strategies and only later in method courses and field experiences to the content-specific skills, concepts and methods connected to technology. The challenge with this kind of approach is to find connections to content-specific methods. Instructional strategies that have revealed promising signs of TPACK development are: instructional design, TPACK-based case development, reflection, and field experience (Koehler et al., 2014; Mouza, 2016).

The fifth path, 'Overall development of TPACK', replaces educational technology courses and instead favours method courses and field experiences where technology-supported strategies are systematically integrated throughout the whole teacher education programme. For example, Tondeur, Roblin, Braak, Fisser and Voogt (2013) found in their study that teacher education institutions in Belgium are undergoing transition from separate stand-alone ICT courses towards embedding ICT across courses. Developing TPACK throughout teacher education has been criticized due to the cognitive load of handling all the knowledge areas at the same time. Using the 'Learning Technology by Design' approach has proved to be an effective way of developing pre-service teachers' TPACK, where PCK and TPACK are developed simultaneously. In this approach, (preservice) teachers work in teams and design solutions to real world problems of teaching and learning, which require them to integrate content, pedagogy and technology (Koehler et al., 2014; Mouza, 2016).

In addition to these five pathways, in earlier sections about TPACK constructs it was shown there are different views of how specific knowledge areas of TPACK affect the overall TPACK and how meaningful they are for the development of pre-service teachers' professional knowledge. While pre-service teachers' TPACK development is found to be connected with their changing identity from learners to teachers, integration of TPK, TCK and TPACK into studies is helping them in this change (Özcün-Koca et al., 2009/2010). In conclusion, it can be said that the ways in which TPACK develops among pre-service teachers varies and, as the research suggests, so too is there variation in the influence of different knowledge areas.

2.6 CHALLENGES AND CRITIQUE WITH TPACK

The fact that the TPACK framework builds upon Shulman's (1986, 1987) concept of PCK, also brings its challenges to the framework. Graham (2011) calls this an "unsure foundation". PCK has been criticised due to imprecise definitions of its concepts, which

leads to difficulties in measuring it. These same problems with imprecise definitions also compromises the TPACK framework. Although, the TPACK framework is easy to understand on the surface, at the conceptual level it has broad and ill-defined concepts. The framework is both simple and easy to understand, and at the same time it is subtly complex. Graham (2011) says it is urgent that deep understanding of TPACK is reached without it becoming too complicated to “all but a few elite researchers”.

A further difficulty, discussed earlier, is that the relationship between TPACK constructs is unclear, i.e. whether the relationship between the elements of TPACK is integrative or transformative (Graham, 2011). Integrative means that TPACK is seen as an integration of major knowledge areas (technology, pedagogy and content). The common representation of the TPACK framework as a Venn diagram (see Figure 1), refers to this kind of relationship. The transformative view projected by Angeli and Valanides (2005), on the other hand, explains TPACK as a unique, distinct body of knowledge, where the growth in the major knowledge areas does not automatically result in growth of TPACK. Difficulty defining boundaries between TPACK elements also causes problems with accurate knowledge categorisation or discrimination. This affects the precision of the framework (Angeli & Valanides, 2009). There are problems, especially with distinguishing adjacent constructs (Cox, 2008).

Cox (2008) criticized TPACK stating that it remains mainly a theoretical framework and that there is no clear method for its implementation and evaluation. She also mentioned lack of both a full definition and examples of TPACK constructs. In the research literature, actual surveys for measuring or auditing different areas of TPACK, describing the strong and weak areas of TPACK, are few (Valtonen, Kukkonen, Kontkanen, Mäkitalo-Siegl & Sointu, 2018). Lack of these might affect the value of TPACK compared to other approaches used in a field of technology integration and also PCK (Angeli & Valanides, 2009).

So far, TPACK research has been concerned mainly with the “quality of” teachers’ or pre-service teachers’ TPACK as a whole without taking into account individual differences within groups. Teachers and pre-service teachers are described in many studies as a homogenous group according to their TPACK level, although the situation is somewhat different (see Valtonen et al., 2018). However, like in every area of life, differences exist and when finding ways to educate pre-service teachers, these differences need to be taken into account. Jordan (2011) discusses gender differences in TPACK and suggests that teacher education programmes need to pay attention to them. According to Jordan (2011), female pre-service teachers are more confident with PK, while male pre-service teachers are more confident with TPK and TPACK overall.

2.7 DEFINING TPACK CONSTRUCTS IN THIS DISSERTATION

As it was mentioned earlier, there are several different definitions for different knowledge areas of TPACK (Cox, 2008). However, it has been stated that the precise construction of a framework is important from the point of view of its development and assessment (Angeli & Valanides, 2009). In order to present a more comprehensive view of TPACK in this dissertation, some theoretically compatible models were used to open up the TPACK framework during the research process. These models are introduced next.

As noted earlier, previous studies have used other, related, theoretical frameworks to investigate (pre-service) teachers TK and for the research reported in this disser-

tation Roger's 'Model of Diffusion of Innovation' (1995) was adapted and used in Study I as a lens into pre-service teachers' abilities with technology (cf. Valtonen et al., 2011). Based on Rogers' model, people can be categorised as late minority and avoiders (originally termed 'laggards'), late majority, early majority, early adopters, and innovators (Rogers, 1995) according to the way they engage with technology. Late minority and avoiders are generally not interested in new technologies while early innovators are interested in technologies in general and ready to try new technologies independently. The categorisation of today's pre-service teachers as the Net Generation (Tapscott, 2009) or digital natives (Prensky, 2001 a,b), suggests their technological abilities should be at the level of innovators or at least early adopters. If students in teacher education were like this, there would be no problem in teaching them about ICT as part of education. But recent research has shown them to be more likely in the category of early majority or late majority (Valtonen et al., 2011) and also the notion that this group of students is homogenous in their abilities with technology has proved to be false (cf. Kirschner & Merriënboer, 2013; So et al., 2012). In addition, researchers have found that although students of today are comfortable with technology during their free time, they do not necessarily see it as a tool for learning and work (Lei, 2009). This makes integration of technology and developing the TK of pre-service teachers important but challenging. In this dissertation, Roger's (1995) model, Net generation assumptions and critiques, and pre-service teachers' understandings of the affordances and constraints of technologies (cf. Voogt et al., 2016) were taken into consideration when investigating pre-service teachers' TK.

In the theory section 2.4.1 (PK - Pedagogical knowledge), the extent to which the TPACK framework can be taken to be pedagogically free was discussed and some ideas from the research literature of connecting it with certain pedagogies were presented. Lee et al. (2012) used a student-centred pedagogy point of view while examining pre-service teachers' PK. Gao et al. (2011) saw that preservice teachers' positions with regard to PK on the student-centred, teacher-guided continuum are connected to their overall TPACK development (see Kember, 1997), where a teacher-guided conception means transmitting information from teacher to learner, and a learner-centred conception means learning directed by students. This has strong similarities to the framework of Bereiter and Scardamalia (1987). Therefore, in this dissertation, in Study I, the way of examining and categorising pedagogical knowledge is through Bereiter and Scardamalia's (1987) framework. This framework uses hypothetical teachers A, B and C to outline different operational models of teaching, and different PK. Teacher 'A' approaches the learning situation with teacher-centred actions and assigns a passive role to the students. Teacher 'B' builds on students' existing knowledge in their teaching. Teacher 'C' acts as a facilitator of learning, gives an active role to the students, and expects them to take more responsibility for their learning. The teacher 'C' operational model of teaching or student-centred conceptions of learning aligns with constructivism as a learning theory (see Bramald, Hardman & Leat, 1995). Since constructivism as a learning theory is one of the prevailing approaches of the national curriculum in Finland (Finnish National Board of Education 2014), using this structure, i.e. examine operational models of teaching, when investigating PK is worthwhile. Constructivist learning theory, and especially the operational model approach, were instrumental in the interpretation of the research data. In addition, in Study III, role play as a constructivist method to teach was the pedagogical stance of the experiment (see more detail in research article III).

In this dissertation, the focus of pre-service teachers' CK was not specified in detail in Studies I and II. In Study III, the experiment for pre-service teachers was about a certain content area, sex education, to answer the need identified by Angeli et al. (2016) for research in a specific subject domain.

One way to concretise TPK, which was used in Study I, is to compare it to Koschmann's (1996) developmental paradigms of ICT. These four paradigms connect learning theories with technologies. The first paradigm, computer-assisted instruction (CAI), is based on programmed instruction, for example, drill and practice. The second paradigm, intelligent tutoring systems (ITS), models the learning process with the help of computers' tutoring, guidance and evaluation of students' learning. In both of these paradigms the role of the teacher or the computer is dominant and instruction becomes more or less information transmission. The other two paradigms, micro-worlds and computer-supported collaborative learning (CSCL), place more emphasis on students' active roles. The micro-world paradigm consists of students' designing, building and testing ideas in different learning environments. The CSCL paradigm emphasises especially collaborative learning with the teacher and other students where the role of the computer is a tool for supporting collaborative knowledge building and knowledge sharing (Koschmann, 1996). In this dissertation, the collaborative knowledge building and knowledge sharing approach was seen as appropriate ways to use ICT in education, as they are emphasised in the new Finnish Curriculum for basic education (Finnish National Board of Education 2014) and are central mechanisms in developing 21st century skills (see Binkley et al., 2012).

2.8 RESEARCH METHODOLOGY IN TPACK LITERATURE

Despite its quite short history, a large number of studies have focused on TPACK. The methodology used in these is typically quantitative survey, i.e. self-reported assessment of pre- or in-service teachers' TPACK (Voogt et al., 2013). Self-efficacy is usually seen as a good predictor of actual teacher behaviour (Tschannen-Moran & Hoy, 2001). However, according to Agyei and Keengwe (2014), self-reported surveys are limited to measuring individual beliefs and information about an individual's TPACK awareness. Consequently, according to Chai, Coh and Tsai (2016), gaining a comprehensive picture of teachers' TPACK would require both quantitative and qualitative methodologies at a general TPACK level and with specific technology, pedagogy and content. Figure 3 represents the methods of TPACK research according to three extensive reviews of research by Koehler, Shin and Mishra (2012), Archambault (2016) and Chai et al. (2016). In their categorisation of TPACK research methods Koehler et al. (2012) do not distinguish between qualitative and quantitative research paradigms. Instead, they present five major categories: open-ended questions, self-assessment tools, performance assessment, interviews and observations, where "only" selfassessment tools, could be seen "purely" as a quantitative method and others can be both. Archambault (2016) concentrates on qualitative methods: performance assessment, observations and interview measures. Chai et al. (2016) concentrates on quantitative methods of survey, measuring lesson design competencies and content analysis of TPACK lesson design.

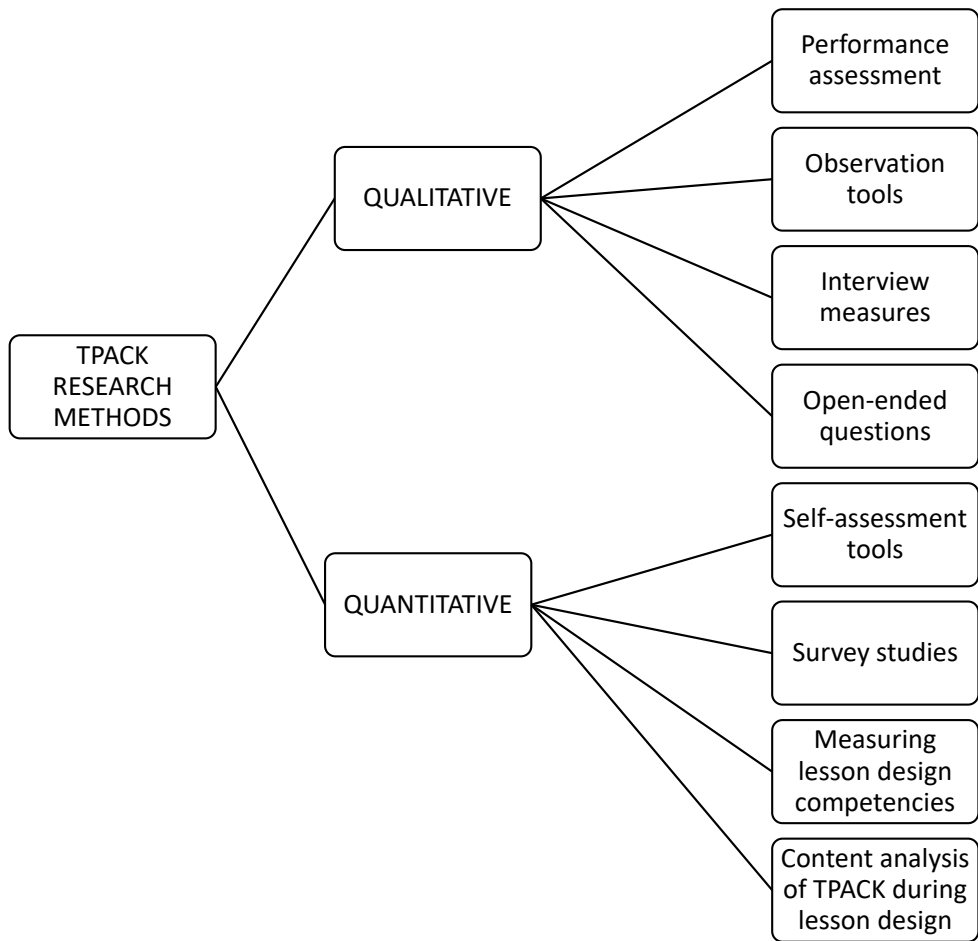


Figure 3. TPACK research methods according to Archambault (2016), Chai et al. (2016) and Koehler et al. (2012).

3 AIMS AND RESEARCH METHODS

3.1 AIMS AND RESEARCH QUESTIONS

A review of the literature reveals rather an unstructured picture of pre-service teachers' TPACK and its development. Therefore, the main aim of this dissertation is to develop a clearer understanding of pre-service teachers' developing TPACK. To reach this aim, this dissertation brings together findings from three studies in answer to the research questions, which are presented in Table 2. During the dissertation process, the two sub-aims of developing a refined proto-TPACK model and proposing a proto-TPACK model with potential application in pre-service teacher education were created. As Cox (2008) stated, the TPACK frame remains mainly a theoretical framework and there is no clear method for its implementation and evaluation. The sub-aims were created particularly to answer this critique.

Table 2. Research questions in this dissertation and in study articles.

	Research questions in this dissertation	Related research questions in published articles
Study I	What do pre-service teachers' perceptions of ICT-use in education reveal about their baseline knowledge of TPACK?	What proto-technological knowledge do pre-service teachers have?
		What proto-pedagogical knowledge do pre-service teachers have?
		What proto-technological pedagogical knowledge do pre-service teachers have?
Study II	How does a technology rich learning environment during upper secondary school affect pre-service teachers' starting points with TPACK?	What advice would students give to (i) new students and (ii) new teachers, based on their experiences of using iPads?
		How does this advice reflect the students' developing proto-TPACK? (their baseline knowledge)
		How does this advice reflect students' opinions about how their teachers utilised TPACK when using iPads? (Do they recognise TPACK and its potential)
Study III	What contribution can an authentic learning experience during teacher education make to the development of the pre-service teachers' TPACK?	How did the pre-service teachers experience the Second Life environment in their own learning?
		How did the pre-service teachers reflect on their experiences with Second Life and what views did they have about its use in their future teaching? (Accessing constructs of TPACK through empathy-based stories and reflective discussions)

In section 2.5.2 five different pathways for developing TPACK in teacher education according to the research literature were presented (see Figure 2). This dissertation connects through its research frames especially to three different paths: Study I is situated in a general educational technology course (path 2: General educational technology course). In Study III the experiment was aiming to develop all the knowledge constructs (path 5: Overall development of TPACK) and the way the experiment was conducted used modelling (path 1: Modelling). The modelling idea was also the pre-

vailing idea in Studies I and II, where participants' previous experiences in school were seen as modelling. In Study II, previous experiences were collected from upper secondary students while experiences as a learner in school have been reported to strongly affect beliefs and assumptions about teaching and learning, especially at the beginning of teacher studies. In addition, previous studies have reported pre-service teachers' difficulty to detach their school experiences from their teacher education experiences. (see Bryan, 2003; Knowles & Holt-Reynolds, 1991; Pajares, 1992; Levin & He, 2008; Lortie, 1975; Wall, 2016) Therefore, in Study I, experiences of ICT use in education, were asked immediately after three years school experiences in technology rich environment to get an insight into the grounds on which pedagogical thinking of pre-service teachers', and TPACK as part of it, is built.

Next, the philosophical foundation of this dissertation is presented followed by a description of the research strategy, subjects and data collection methods in the research studies. Finally, in this section, data analyses are described.

3.2 CONSTRUCTIVISM AS A PHILOSOPHICAL FOUNDATION

Philosophically this dissertation is based on constructivism. In the context of the dissertation the constructivist research paradigm has been applied as follows.

Constructivism as a research paradigm endeavours to understand subjective human experiences. The goal of constructivist research is to understand and interpret research participants' thinking and understandings in the situation being researched. In the research literature, constructivist and interpretivist paradigms are closely connected (see Kivunja & Kuyini, 2017, Schwandt, 1994). The term constructivism points especially to the paradigm's central tenet of reality being socially constructed (Bogdan & Biklen, 1998). In this dissertation, the research is approached from the constructivist perspective because it seeks to understand and interpret pre-service teachers' and upper secondary school students' (the research participants) different views and perceptions of ICT in education (the research context) and in this way to enrich earlier TPACK research. As pre-service teachers usually do not have many experiences with ICT integration in education as teachers, the aim is to gain insight into their experiences of it as learners and therefore their time in upper secondary school was taken to be formative. This aligns with Wall's (2016) research where learning to teach was seen as a constructive process that commences long before individuals begin teacher education programs. Again, aligning with Wall's (2016) research, TPACK is seen as a developing and constantly evolving entity based on experiences of teaching and learning and experiences with ICT (Voogt et al., 2013). TPACK is also a frame affected by the rapid technological developments, allowing (pre-service) teachers to find new possibilities and ways to develop their teaching with ICT.

The epistemology of constructivism is subjective, i.e. the researcher interprets the data through his/her own thinking and cognitive processing in interaction with the participants. The researcher is part of the reality he/she is exploring and his/her personal experiences of real life affect the knowledge gained from the research (Kivunja & Kuyini, 2017). From the epistemological point of view, the knowledge in this dissertation is seen as subjective and transactional, shaped through interactions between the researcher and the research participants. In the studies presented, participants construed their experiences with ICT in education individually (in Study I through open-ended questions; in Studies II and III through empathy-based stories) and collab-

oratively (in Studies II and III, through reflective group discussions). The researcher's understanding of the phenomena and her knowledge of previous research affected how the research was conducted. In addition, the researcher's values, earlier experience as a student, a pre-service teacher, a teacher, and a teacher educator, affected how the data was interpreted and analysed.

The ontology of constructivism is relativist, i.e. the situation studied has multiple realities, which are constructed by participants. Social interaction with others and personal histories shape participants' understandings (Creswell, 2009). The realities of the researchers and research participants, preservice teachers and upper secondary school students, are differently shaped according to their experiences, study histories, contextual factors etc. Despite the unique and personal interpretations of reality, the Finnish school system is rather homogenous and therefore it was expected in this dissertation to find features and meanings of ICT use in education that are shared with common understandings. The different views and realities enrich the interpretation and the picture of preservice teachers' TPACK.

According to Kivunja and Kuyini (2017), constructivism assumes a naturalistic methodology which means that data are gathered through interviews, discourses, text messages and reflective sessions, where the researcher is acting as a participant observer. Heikkinen, Huttunen, Niglas and Tynjälä (2005) mention that constructivism involves finding and making interpretations of reality from which it follows that there is no universal methodology, rather a range of methodological possibilities that can be adapted to suit the research situation. The research methods chosen for this dissertation are those which were found most suitable for getting answers to the research questions, to help preservice teachers acknowledge and bring out their experiences, and to explore the ways they build the themes related to ICT in education and their TPACK. This leads to a balanced axiology of constructivism, which means that although the values of the researcher affect the outcomes of the research, this is concretised by the use of versatile research methods, in making the process of research as visible as possible, and in reporting accurately and in detail all the phases of the research (Kivunja & Kuyini, 2017).

3.3 RESEARCH STRATEGY, SUBJECTS AND DATA COLLECTION METHODS

The research strategy of this dissertation is qualitative survey in the first two studies and in the third, a case study. The dissertation is not a follow-up but a cross-sectional study of pre-service teachers' and upper secondary school students' TPACK. Investigating various groups of learners in various contexts enables the researcher to get a more versatile picture of the TPACK development of pre-service teachers' than by following up one group of students alone.

Challenges and critiques of the TPACK framework were presented in section 2.6. In order to overcome these challenges methodologically in this dissertation, they were taken into account when designing the research frame of studies. The criticism that TPACK research is based mainly on self-assessment using the researchers' pre-determined scales (see Voogt et al., 2013), was answered by setting up the frames so that the "products" of informants, i.e. their texts, empathy-based stories and reflective group discussions, defined the content of their TPACK. Qualitative methods of data collection and analysis were a way of opening up the definitions according to the in-

formants' own knowledge levels and to answer the criticism of imprecise definitions in the TPACK framework. Earlier research has acknowledged only a little variation among different teacher groups and individuals. This dissertation brings to the fore the early phases of the education of pre-service teachers and their developing TPACK. The use of the pre-service teachers' "own voice" was designed to bring out the variation among them.

The research subjects in Study I were first-year pre-service teachers (n= 146) majoring in home economics, textiles, early childhood education or they were general class teachers. The data was collected during the 'Pedagogical views of ICT in education' course (first ICT in education course) at the University of Eastern Finland. In Study II, the research subjects were upper secondary school third year students (n= 84), from an upper secondary school in Finland, where all the students were provided with iPads at the start of their studies. In Study III, the context of study was a Second Life experiment in an optional course 'Pedagogical views of Human biology' for second year primary school pre-service teachers (n=19).

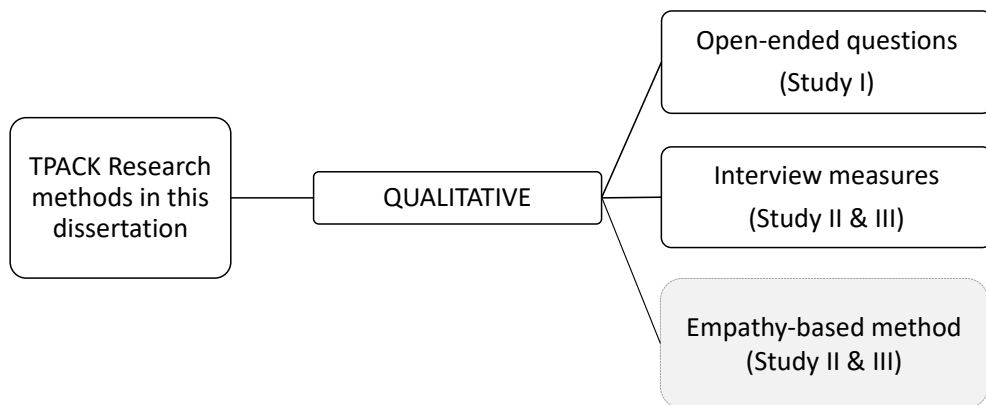


Figure 4. TPACK research methods in this dissertation.

In this research, data collection methods and analysis are mainly qualitative; only some descriptive statistics are presented in Study I (see Figure 4 and Table 3). In Study I, the data collection method conforms to the Koehler et al. (2012) category 'Open-ended questions' (see Figure 3 and section 2.6). In both studies II and III data were collected with reflective group discussions and the empathy-based method. Reflective discussions could be assimilated with group interviews i.e. interview measures in Figure 3 and 4. The empathy-based method, with respondents' reflective stories, with its unique features, is a new method compared to the earlier-presented data collection methods of TPACK (see Figure 3). Introduction of new methods into TPACK research is one of the contribution made through this dissertation. Next, the data collection methods of this dissertation are presented more in detail.

Table 3. The empirical studies, their design and research topics, data sources and main methods.

Study (article)	Research question	Subjects	Research strategy and topic	Method/ Data source	Data analysis
I	What do preservice teachers' perceptions of ICT-use in education reveal about their baseline knowledge of TPACK?	Preservice teachers (n= 146)	Cross-sectional survey to explore pre-service teachers' developing technological pedagogical knowledge (TPK), so called proto-TPK	Answers to the open-ended questions	Qualitative theory-guided content analysis and quantification of results by frequencies, percentages, cross-tabulation and chi square test
II	How does a technology rich learning environment during upper secondary school affect pre-service teachers' starting point with TPACK?	Upper secondary school students (n= 84)	Cross-sectional survey to discover upper secondary school students' experiences of using iPads as a part of their studying and learning. Contribution of the iPad experiment to the starting point for the development of the pre-service teachers' proto-TPACK	Reflective group discussions Empathy-based stories	Qualitative thematic analysis
III	What contribution can an authentic learning experience during teacher education make to the development of pre-service teachers' TPACK?	Preservice teachers (n=19)	Case study to investigate preservice teachers' experiences of using SL as a technological tool for discussing sensitive topics in sex education and, in the light of their experiences, explore how they thought SL might be used pedagogically in their future teaching	Reflective group discussions Empathy-based stories	Qualitative theory-guided content analysis

3.3.1 Open-ended questions, 'texts'

Open-ended questions are often connected to surveys with multiple choice questions, leaving the possibility for respondents to open up and share personal views and comments. This way respondents feel that the data are more personal and they are encouraged to take a greater sense of responsibility for it. It is said that (more) authentic, honest, deep and rich data can be achieved with open-ended questions (Cohen, Manion, & Morrison, 2007). According to Koehler et al. (2012), open-ended questions are one category of TPACK research.

In Study I, the data consists of pre-service teachers' answers to the open-ended questions, or 'texts' as we called them in the published article. Koehler et al. (2012) noted in their review that this methodology is typical in TPACK research asking "pre- or in-service teachers to write about their overall experience in an educational course or professional development programme that emphasises the TPACK". In our study,

pre-service teachers answered six open-ended questions (see Table 4) in the Moodle environment on their knowledge of and skills with ICT and their educational experiences of it during their minor course in 'Pedagogical views of ICT in Education'. A framework for localized and contextualized use of ICT was used as a foundation for the questions (Vesisenaho & Dillon, 2013). The length of individual answers varied between 65 and 895 words. According to Koehler et al. (2012), open-ended questions are used in fewer studies compared to other categories (see Figure 3). In their opinion, this is because of the complexity of coding and analysing data from open-ended instruments. In Study I, the complexity of coding was present, but the use of theory-guided content analysis from the perspective of TPACK and the operational model of teachers (Bereiter & Scardamalia, 1987) gave a rigorous frame of analysis.

Table 4. Open-ended questions.

1a My own experiences of using ICT (Free time)
1b My own experience of ICT and education (as pupil and university student) (School)
2a My knowledge about ICT in education (Knowledge)
2b My skills of ICT in education (Skills)
2c My experience of using ICT in education as a teacher (Experience)
3 My vision of ICT in education in the future (Vision)

3.3.2 Reflective group discussions

Reflective group discussions were used in Studies II and III of this dissertation. Reflective group discussions have similarities with the research method of focus group discussions (see Sagoe, 2012; Wong, 2008). Focus group discussions are small group discussions where 4–12 individuals have a discussion about their personal experiences with the topic (Sagoe, 2012). Even though some researchers perceive focus group discussion as a group interview, there is a clear distinction between them. The distinction is one of interaction, i.e. in interviews there is little interaction and in discussions the situation is based on interactions between participants. Focus group discussions are used in social and behavioural sciences for exploring people's knowledge and experiences. They are used to examine and discover the content but also the reasoning behind people's thinking (Sagoe, 2012). The features of these methods fit with the research aims of both studies II and III.

In focus groups, there is normally a moderator who guides the conversation. In this research, instead of having a moderator, the discussion tasks for students (in Study II) and pre-service teachers (in Study III) were specified (see Table 5). All the discussions in Study III (n=4) were audiotaped and in Study II (n=4) audio- and videotaped.

Table 5. The tasks for reflective group discussions.

Study	The tasks for reflective group discussions
II	Three years of the iPad experiment are behind us. What worked well, what did not? Discuss and record the ideas. According to your discussion, create instructions for the use of iPads in studying for both students and teachers. Present your final instructions for both students and teachers in a Word document.
III	Reflect on your experiences of the course through the following questions: <ul style="list-style-type: none"> • What did you learn about Second Life through the experiment? (TK) • What did you learn about sex education? (CK, PCK) • What factors supported/did not support your learning? (PK, PCK, TPK, TPACK) • How could you apply these experiences in your future as a teacher? (PCK, TPK, TPACK) • How could you utilise role playing in a virtual environment in your future as a teacher? (TPK, TPACK)

3.3.3 Empathy-based method

The empathy-based method (eläytymismenetelmä in Finnish) is a data collection method where respondents are asked to write a short story. The stories are written according to instructions and an orientation of the text created by the researcher. In this method, variation in the orientation text is central, i.e. respondents receive different versions of it. In the different versions, the variation is normally only in one aspect of text and respondents are not aware of the different versions. The empathy-based method is especially used and developed in Finland in social and educational studies. The origins of this method are in the role-play (Eskola, 1998). In the role-play method, there are two trends: active role-playing and passive role-playing (or non-active role-playing) (Ginsburg, 1979). The empathy-based method aligns with passive role-playing. This method is described as economic and flexible. According to earlier studies undertaken with the method, 10–15 stories per orientation text are considered enough to catch essential theoretical features of the phenomenon. There is flexibility in the analysis phase because the data can be read and analysed in several different ways: quantification of data, qualitative methods, and discursive analysis (Eskola, 1998). This flexibility was one of the reasons for choosing the data collection method in Studies II and III. Moreover, this data collection method is novel in TPACK research. One of the challenges with empathy-based method is the question of authenticity of the stories. However, the feedback discussions with respondents in earlier studies have shown that even though the situation and the teller of the story are imagined, the respondents write mainly about their own experiences. Another challenge with the empathy-based method concerns the stories being “typical” and expected (Eskola & Suoranta, 2005) However, these typical stories have their significance because they are exposing respondents’ thoughts about the topic (Eskola, 1998).

The empathy-based method for data collection was used in this dissertation in Studies II and III. In the Study II, all of the respondents (n=68) received two orientation texts about writing ‘advisory letters’ to both new students and teachers (see Table 6). This yielded 127 stories, 65 letters to students, 62 letters to teachers. In Study III, pre-service teachers (n=19) received one of the two different orientation texts (imagined scenarios, see Table 6) and were asked to write as a teacher about their positive or indifferent experiences of using a Second Life environment in their teaching. During their writing, they were not aware of other variations of the orientation text. The data

consisted of 19 stories, 10 of positive experiences and 9 of indifferent experiences with the Second Life environment.

Table 6. Orientation texts.

Study	Orientation text	Variation
II	Write a letter to a new student/teacher in an upper secondary school with the title: Instructions for iPad use in studying.	A new student/ a new teacher
III	As a teacher you have had a positive/indifferent experience of teaching a module using the Second Life virtual learning environment. What happened and why? Describe pedagogical, technological and content features of the module you 'taught'.	A positive experience/ a indifferent experience

3.4 DATA ANALYSIS

Qualitative theory-guided content analysis was used in Studies I and III, and in Study II it was qualitative thematic analysis (see Figure 5.). Both these methods of analysis are said to be flexible and suitable for different kinds of data. In addition, they have similarities in the phases of the analysis and both acknowledge deductive i.e. theory driven analysis. These were important reasons for choosing the methods. Next, the methods of analysis and ways of using them in this dissertation are introduced more in detail.

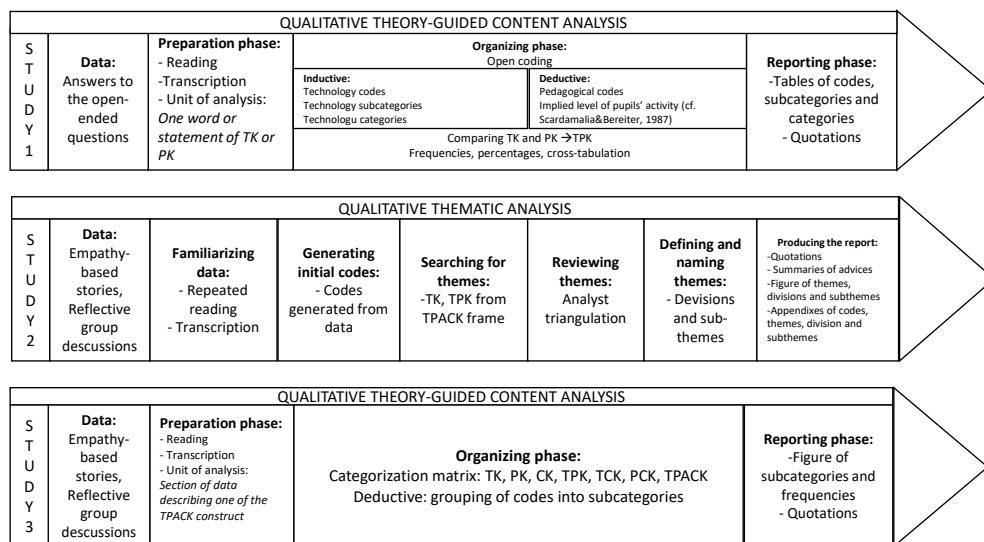


Figure 5. Analysis process.

3.4.1 Qualitative content analysis

According to Cohen et al. (2007), content analysis is a one main form of qualitative data analysis. Content analysis is a procedure where a large amount of written data is reduced to “manageable and comprehensible proportions”, i.e. data reduction. In contrast to this, Gibbs (2012) says that qualitative analysis does not reduce or condense the data but may add to the volume during the analysis process and only in the reporting phase is the data presented using summaries and examples. A simple definition of content analysis is a description of the process of summarising and reporting written data. However, strictly defined, content analysis is “a set of systematic processes for rigorous analysis, examination and verification of the content of written data” (Cohen et al., 2007). Elo and Kyngäs (2008) describe the benefits of qualitative content analysis as content-sensitiveness and flexibility in terms of research design. A criticism of this analysis method is that both techniques are said to be too simplistic for detailed statistical analysis and analysis is not qualitative enough in nature. In contrast to this, Mayring (2014) described qualitative content analysis as having some of the strengths of quantitative content analysis, such as embedding of the material within the communicative context, systematic procedure, focus on categories.

In this dissertation the emphasis is on qualitative content analysis, while the statistical analysis is used only in Study I and only for describing the data. According to Mayring (2014), there are two central approaches to the procedure of qualitative content analysis: inductive category development and deductive category application, where the former is analysis according to the data and the latter according to an earlier theory or theories. In Studies I and III the analysis used both approaches. To deepen the qualitative analysis of the data, discourse analysis would have been possibility to analyse texts, reflective group discussions and empathy-based stories. However, we were not interested in power/authorities (*valta-asema*) in the data, which is the key interest in critical discourse analysis (Jokinen & Juhila, 2016). Moreover, because the development of TPACK is the key concern in this dissertation, connecting analysis to the TPACK framework through deductive category application was the better choice.

Elo and Kyngäs (2008) describe content analysis as having three phases: preparation, organising and reporting. In the preparation phase the researcher becomes familiar with the data and tries to make sense of it by reading it several times. Also transcribing video or voice data and moving it to electrical format is a part of this phase. It is also essential to decide and select the unit of analysis, i.e. what to analyse and in what detail. The unit of analysis can be a word, sentence, a theme, etc. and it can contain several meanings. This might make analysis difficult. On the other hand, a too narrow unit of analysis might cause the problem of fragmentation. During this phase it is important to decide if only visible content is to be analysed or also the hidden (latent) meanings (Elo & Kyngäs, 2008).

In Studies I and III, the preparation phase included transcribing the data (in Study III voice records/audiotapes and handwritten texts) into digital form for Atlas-ti 6.2.-software and reading the data several times (see Figure 5). The unit of analysis in Study I was one word or statements containing a few sentences of Technological Knowledge (TK) or Pedagogical Knowledge (PK). In Study III, the unit of analysis was a section of data where the data described experiences concerning one of the TPACK framework knowledge areas; technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), techno-

logical content knowledge (TCK), pedagogical content knowledge (PCK) and technological pedagogical content knowledge (TPACK).

The next phase, organising, depends on whether the study is inductive or deductive. An inductive study, also called 'conventional approach' (see Hsieh & Shannon, 2005) includes open coding, also called 'data-driven coding' (see Gibbs, 2012), creating categories and abstractions. In our Study I, the open coding was used at the beginning for the data. Technological codes found were then categorized under data-driven subcategories and categories. In a deductive study, also called 'directed approach' (Hsieh & Shannon, 2005) or 'theory-guided content analysis' (term used in in Studies I and III, see Gibbs, 2007; Miles & Huberman, 1994; Savenye & Robinson, 2005), the coding is concept-driven (see Gibbs, 2012), i.e. the categorisation matrix is developed according to earlier studies or theories (Elo & Kyngäs, 2008). In Study III, the coding started with putting sections of data under categories derived from TPACK constructs. After that codes under each knowledge category were grouped into subcategories according to similar content. Also, Study I used this approach partly after open-coding. The pedagogical codes were located to categories derived from the model of teachers' operations (Bereiter & Scardamalia, 1987). Validity of this phase was ensured in Study I with analyst triangulation i.e. the data were partly coded by another trained research assistant and a measure of agreement was calculated. In Study III, research group negotiations during the analysis process increased the validity.

In Study I, after categorisation of technological codes and pedagogical codes, categories were compared, i.e. how different technologies (technology categories) were used for supporting learning (pedagogical categories). In addition to qualitative analysis, frequencies and percentages of technological and pedagogical codes and categories were calculated. This phase involved also crosstabulation of technological categories and pedagogical categories with chi square tests. The aim was to detect differences and similarities between uses of technologies in different pedagogical categories.

In the reporting phase of both Studies I and III, quotations from different categories and subcategories were presented. In Study I, also tables of codes, subcategories and categories as well as a cross-tabulation table of technological knowledge and pedagogical knowledge were given. In Study III, a figure with frequencies of subcategories was presented to clarify the analysis. This reporting phase with quotations, tables and figures is essential in assuring the validity of the studies. More about the validity of analysis is addressed in the Discussion section (6.3 Methodological reflections).

3.4.2 Thematic analysis

While in Studies I and III, qualitative theory-guided content analysis was adopted, in Study II, we explored thematic analysis in order to test its suitability to analyse the data collected deductively from the perspective of the TPACK frame.

Braun and Clarke (2006) describe thematic analysis as a widely used foundational, qualitative, analytic method, especially in psychology, but also elsewhere. In thematic analysis, researchers identify, analyse and report patterns (called themes) within the data. Flexibility is mentioned as one of its benefits, along with its theoretical and epistemological freedom (Braun & Clarke, 2006). Guest, MacQueen and Namey (2012) describe thematic analysis as being well-suited for large data sets. Missing some of the more nuanced data is a limitation of the method according to Guest et al. (2012). Again, as mentioned with the qualitative content analysis of Studies I and III, to get

more precise nuances of the data, discourse analysis would have been a possible way to analyse reflective group discussions and empathy-based stories.

Although thematic analysis is widely used, there is no general agreement about how it should be done. A theme is connected to the research question and it reveals something important from the data. As with qualitative content analysis, thematic analysis can be inductive, i.e. data driven, and/or deductive, i.e. theoretically driven (Braun & Clarke, 2006). In Study II, the thematic analysis was deductive, themes arose from the TPACK constructs (see Figure 5).

Braun and Clarke's (2006) description of thematic analysis was used to guide the analysis process in Study II; it provided a clear frame in which to conduct the analysis. Braun and Clarke (2006) describe six phases of thematic analysis; familiarising data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. They say the analysis is not a linear process, but moves back and forth throughout the phases. The familiarising phase includes data transcription and reading the data several times; like-wise in qualitative content analysis. In Study II, this phase included transcription of voice records and students' handwritten texts into digital format and to Atlas-ti 6.2. software.

The next phases, generating initial codes and searching for themes, are used to identify interesting data features for analysis and sorting these into potential themes. In the case of theoretically driven thematic analysis, the codes or themes arise from earlier research. In Study II, codes were generated from the data, but the themes of technological knowledge and technological pedagogical knowledge came from the TPACK framework. These phases were done individually by the two researchers and then through discussion shared understanding was negotiated ambiguities were resolved. This improved the validity of the analysis. After and according to the negotiation, one researcher continued the analysis to the phases of reviewing, naming and defining themes, where themes and codes and a thematic map are considered carefully (Braun & Clarke, 2006). In these phases, codes under the themes of TK and TPK were organized into divisions and then sub-themes based on similarities.

The reporting phase includes descriptions of the data with suitable examples or extracts from the data and making an argument in relation to the research questions (Braun & Clarke, 2006). In Study II, the report consists of a description of themes, divisions and sub-themes with quotations. Also, summaries of advice for teachers and students were given. Summaries align with the type of stories used sometimes with empathy-based methods to present the essential findings in clear form (see Katila & Eriksson, 2013; Posti-Ahokas, 2013). Arguments were also given in the conclusions of the paper. Descriptions of the themes, divisions and sub-themes with quotations, summaries, and arguments in the conclusions help assure the validity of the analysis, i.e. they make it easier for the reader to follow the logic of how the analysis was conducted.

4 AN OVERVIEW OF THE EMPIRICAL STUDIES

The first study in this dissertation addresses the experiences of ICT-use of pre-service teachers at the very beginning of their studies. As it was the first research I conducted during my dissertation process, and it was during a project where I was required to help teacher educators to include pedagogically sound technology in their courses, it helped me to get an understanding of the situation with regard to pre-service teachers' knowledge and skills of ICT during their free time and schooling. From the results of this study, I composed the framework of proto-TPACK, as I noticed that pre-service teachers' knowledge of ICT-use in education and their TPACK is varied and often quite limited. On the basis of their experiences during school time, it seems that pre-service teachers had had few experiences with ICT. This made me consider if technology rich experiences during school time would help establish a grounding on which to build the pre-service teachers' TPACK. It was a fortunate coincidence that during my dissertation process, the iPad experiment was started in the university practice school, one of the first one-to-one experiments in Finland, and I was able to join the project and to collect research data from it.

As this dissertation is concerned with the development of pre-service teachers' TPACK, it is not immediately obvious why data should be collected from upper secondary school students. The reason is as follows. One of the biggest justifications was knowledge from earlier research about preservice teachers' school experiences and how they strongly affect their beliefs and assumptions about teaching and learning, especially at the beginning of their teacher studies (see Bryan, 2003; Knowles & Holt-Reynolds, 1991; Pajares, 1992; Levin & He, 2008; Lortie, 1975; Wall, 2016). As Wall (2016) states in his study about how pre-service teachers' educational beliefs change, it is difficult for anyone to distinguish the past from the present, i.e. for pre-service teachers to detach their prior schooling experience from their present studies in teacher education. Therefore, in Study II, third year students in an upper secondary school were asked about their experiences with ICT-use in education immediately after having three year's studying with iPads. This gave an insight into the grounds on which the TPACK of pre-service teachers' is built, from a situation where the environment of learning had been a technology-rich one. According to Wall (2016), it is important for teacher educators to know the grounding on which to build instruction in teacher education. This makes it possible to promote conceptual growth and facilitate construction of a more effective framework for thinking about classroom practice.

In addition, investigating these students, who had benefitted from a technology-rich learning environment during their upper secondary schooling, was worthwhile because the new curriculum in Finland (Finnish National Board of Education, 2014), has expectations that, in future, school students should have similar experiences with ICT. In other words, the iPad experiences of the students in this study is relevant to the future direction of education in Finland.

Among the earlier experiences of learning with ICT that affect pre-service teachers' knowledge of ICT in education, Tondeur et al. (2012) emphasised the significance of authentic learning experiences with the technology. Therefore, in Study III, the pre-service teachers were introduced to the Second life environment in the context of

a content concerned with of sex education. They got authentic experiences as a student using a new technological environment for learning.

In addition to earlier mentioned reasons, during the research process the data collection methods and study design were modified according to the emergent research data. In Study I, the aim was to get an overview at the beginning phase of the pre-service teachers' experiences with ICT i.e. their developing TPACK. Even though the amount of data was large, in some cases the answers to the open-ended questions were quite superficial. Therefore, it was decided to add reflective group discussions to studies II and III, to open up and find out the reasoning behind the written texts. Moreover, as ICT is such a wide concept, which means different things to pre-service teachers, in both studies II and III, specific technologies were used to give a better insight into the technological aspects of TPACK, iPads in Study II and Second Life in Study III. Similarly, to gain a better insight into the content aspects of TPACK, Study III focused on a specific content, sex education.

4.1 PRE-SERVICE TEACHERS' EXPERIENCES OF ICT IN DAILY LIFE AND IN EDUCATIONAL CONTEXT (STUDY I)

Kontkanen, S., Dillon, P., Valtonen, T., Renkola, S., Vesisenaho, M. & Väisänen, P. (2016). Pre-service teachers' experiences of ICT in daily life and in educational contexts and their proto-technological pedagogical knowledge. Education and Information Technologies, 21(4), 919-943.

The first study concentrated on pre-service teachers' experiences, skills and knowledge about ICT use in education in the beginning of university teacher training. Pre-service teachers' perceptions were explored through the TPACK theoretical framework and their pedagogical knowledge through Bereiter and Scardamalia's (1987) operational model of teaching. Pre-service teachers, as a part of so called Net Generation, was also discussed. The aim of this study was to explore what knowledge, skills and prior knowledge pre-service teachers bring with them when they enter university teacher training and how these might form the basis for their TPACK development.

The context of the study was 'Pedagogical views of ICT in education' course at the University of Eastern Finland. The target group was first-year pre-service teachers (n= 146) majoring in home economics, textiles, early childhood education, or they were general class teachers. Pre-service teachers were asked to answer six open-ended questions in a Moodle environment on their knowledge of and skills with ICT and their educational experiences of it, yielding 141 "texts". The data were analysed with qualitative theory-guided content analysis, i.e. guided by the TPACK framework and the teacher's operational model (see Figure 6). In addition to qualitative theory-guided content analysis, frequencies and percentages of technological and pedagogical categories were calculated. A cross-tabulation with a chi square test was included to emphasise differences between uses of technologies in different pedagogical categories.

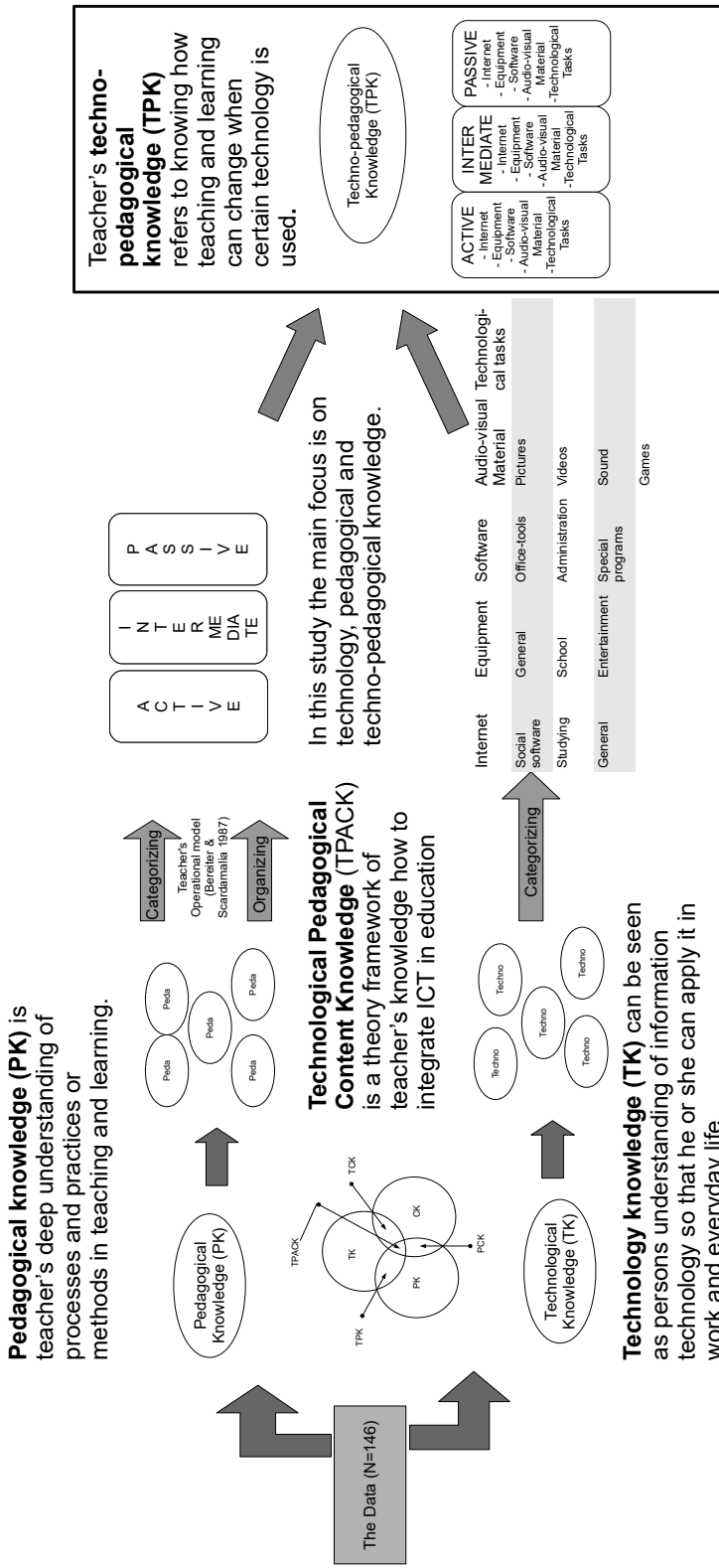


Figure 6. Framework for data collection and analysis in Study I (Kontkanen et al., 2016).

Even though pre-service teachers' texts revealed a variety of different technological equipment and software, data revealed their knowledge of ICT as quite traditional, lacking innovative ideas. Their technological knowledge varied a great deal and it was hard to define these pre-service teachers as a techno-literate or technologically homogenous group. Considering pre-service teachers' pedagogical knowledge, the data expressed mostly teacher-centred ways of teaching. Their prior educational experiences with ICT were also predominantly teacher-centred, i.e. students' roles were passive. In the texts, pre-service teachers saw that the use of ICT is heavily influenced by the teacher implying more passive roles for pupils. The data showed also that pre-service teachers' own experiences of learning with technology are limited. Results suggested that the development of pre-service teachers' pedagogical knowledge and especially their TPK were in the early stages.

According to the results, pre-service teachers' TPK did not resemble that of working teachers' and therefore it was suggested they start their studies with so called proto-TPK, which is a basis for TPACK and which develops and matures during their studies. A tentative model for the development of proto-TPACK was proposed (see Figure 9).

4.2 STUDENTS' EXPERIENCES OF LEARNING WITH IPADS IN UPPER SECONDARY SCHOOL (STUDY II)

Kontkanen, S., Dillon, P., Valtonen, T., Eronen, L., Koskela, H., & Väisänen, P. (2017). Students' experiences of learning with iPads in upper secondary school—a base for proto-TPACK. Education and Information Technologies, 22(4), 1299-1326.

The second study focused on upper secondary students' experiences of using personal iPads throughout their three-year upper secondary school studies. The experiences were viewed through the TPACK theoretical framework to establish how this kind of technology-rich upper secondary environment contributes to the starting point for the development of the pre-service teachers' TPACK.

The context of the study was an upper secondary school in Finland, where all new students were provided with iPads at the start of their studies. Upper secondary school third year students (n= 84) were asked to write short stories (127) about how they would advise a new teacher and a new student to use iPads in teaching and learning. The data included four reflective group discussions on the same topic. The analysis was done using qualitative thematic analysis guided by the TPACK framework where all the data were divided into two themes: Technological Knowledge (TK) and Techno-Pedagogical Knowledge (TPK) (see Figure 7).

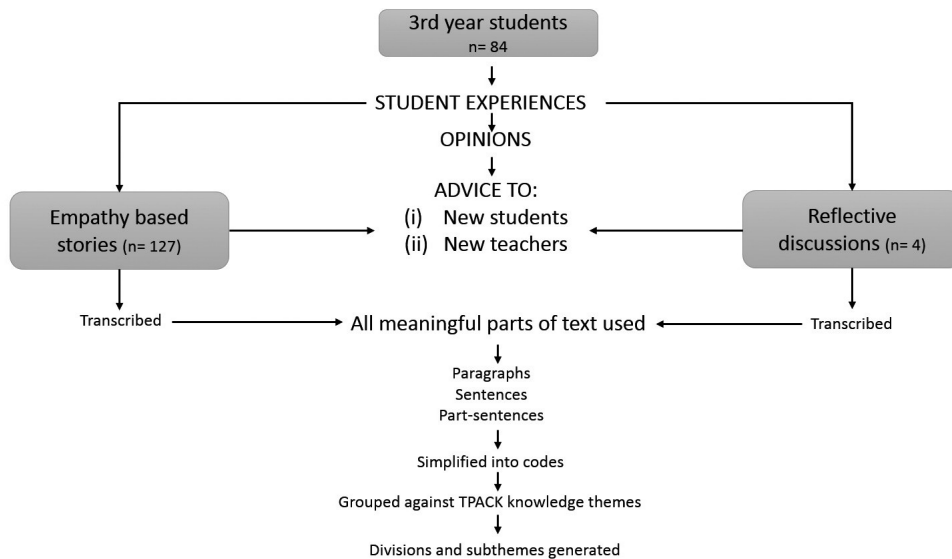


Figure 7. Data collection and analysis in Study II (Kontkanen et al., 2017).

Despite the possibilities offered by the iPad's, in the data students listed mainly iPad applications comparable to office tools. This might be sign of their limited TK or more obviously the limited TK of their teachers, because students were able to recognise well the iPads' technological features. This is again a sign of the limited TK maturity level of students. The data showed students' ambiguous and/or contradictory opinions about the use of iPads in education is, i.e. they wanted freedom to decide how to use iPads in school but were questioning their capabilities to handle the freedom. According to the data, teachers continued to teach the way they did before the iPads, which is a sign of the traditional level of teachers' TPK. Students were also expecting teachers to decide and control the use of iPads, which can be seen as a sign of limited student TPK development. However, a putative sign of the development of their TPK showed students' ability to criticise, suggest tasks, recognize responsibilities in learning and give advice to others for effective learning. Advice given by students was more about knowledge transfer than student-centred learning, denoting that students' development of proto-TPACK were quite limited. Overall, the data revealed that teaching was not fulfilling students' needs for learning and teachers' needs to develop their TPACK. In order to develop the TPACK of students and teachers, both need pedagogical support.

4.3 PRE-SERVICE TEACHERS' EXPERIENCES OF SECOND LIFE EXPERIMENT IN SEX EDUCATION (STUDY III)

Kontkanen, S., Dillon, P., Kärkkäinen, S., Kukkonen, J., Valtonen, T., & Väisänen, P. (2015). A Second Life experiment in sex education with pre-service teachers and its contribution to the development of their proto-TPACK. Journal of Educational Enquiry, 14(3), 17-36.

The third study explored pre-service teachers' experiences using Second Life in a sex education course in teacher education. Pre-service teachers' experiences were viewed through the TPACK framework in order to reflect on the contribution of Second Life to the development of their proto-TPACK.

The context of this study was a Second Life experiment in an optional course 'Pedagogical views of Human biology' for second year primary school pre-service teachers. Pre-service teachers (n=19) participated during their course in the Second Life experiment, where they discussed through role play sensitive issues in sex education (see Figure 8). The data were gathered after the experiment. Pre-service teachers wrote short stories (19) around imagined scenarios of teaching with Second Life and had reflective group discussion (4) in groups of 3-5. The data were analysed using qualitative theory-guided content analysis, i.e. coding was relative to TPACK constructs.

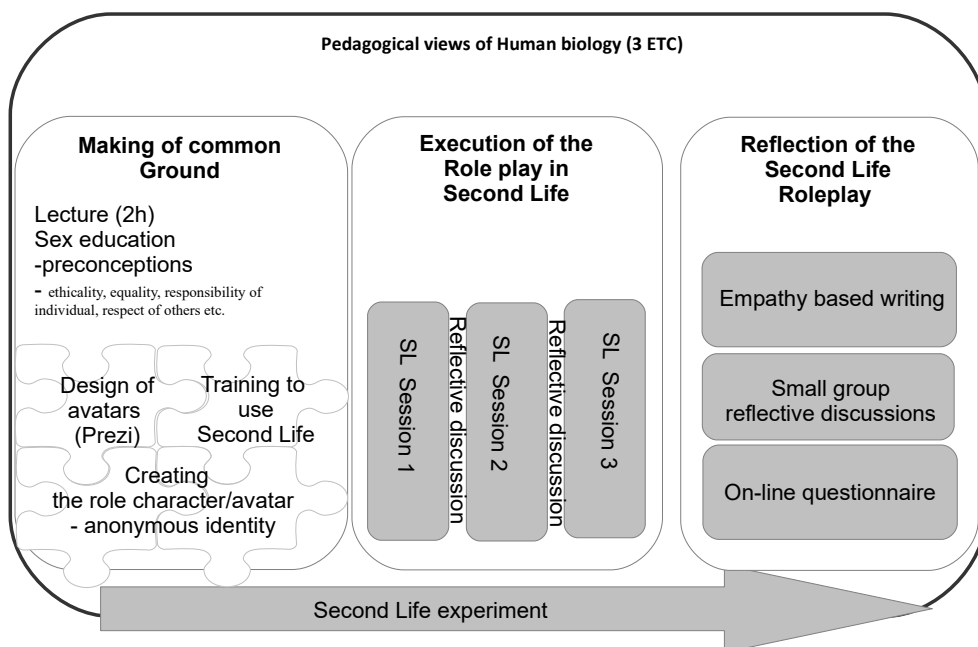


Figure 8. Course design and research design in Study III (Kontkanen et al., 2015).

Although pre-service teachers valued the pedagogical design of the experiment, they saw teaching with Second Life as an area that demanded certain skills outside normal teacher routines. Preservice teachers valued the pedagogical idea of the Second Life experiment, i.e. using role play to discuss sensitive issues. They were able to recognise the advantages of using role play in education and saw anonymous conversations in small groups to be plausible in sex education. Especially valued were the grounding phase of the experiment, where avatars for SL were created, prior experiences were talked about.

The data showed that this kind of experiment, where technology (Second Life), pedagogy (role play, anonymous conversation in small groups) and content (sensitive issues in sex education) are connected, fosters pre-service teachers' thinking about the use of ICT in education in general, i.e. they reflected and developed further their TK and TPK. Development of TK was seen in their ability to use appropriate terminology, and, especially, in recognising the constraints of Second Life. Affordances of Second Life, on the other hand, were not easy to see for pre-service teachers, which is a sign of limited application of their TK, TPK and TPACK.

Overall, the data emphasized pre-service teachers' TK and TPK. Despite the strong connection to sex education and sensitive issues (content) in the experiment, there were just a few mentions about TCK in the data. Hence, the results suggest that TCK is a difficult area for pre-service teachers to engage with. In their stories, pre-service teachers stayed with the pedagogical idea of the experiment, which could be a sign of preference of the idea or of underdeveloped TPACK, i.e. "they are not yet ready to find new ways to connect pedagogy, technology and content". Results suggests that we should implement these kinds of experiments connecting different TK, CK, PK in pedagogically meaningful ways in different phases of teacher education in order to support the development of their TPACK and investigate it in greater depth.

5 RESULTS

This dissertation examines the nature and development of TPACK among pre-service teachers. In Studies I and III the target group was pre-service teachers. In Study II the target group was third-year upper secondary school students in order to find out what kind of skills and readiness we can expect from pre-service teachers entering teacher training. Study I addressed the general use of ICT in education, the Study II iPad use in education and Study III Second Life use in sex education. Study I and II concentrated especially on prior experiences, skills and knowledge i.e. the grounds for building up TPACK. The third study was concerned with experiences in teacher education i.e. developing TPACK in teacher education with authentic experiments.

The results in this dissertation indicate the need for strong support for pre-service teachers and students in upper secondary school. They suggest that pre-service teachers do not have TPACK in the same sense that an experienced or working teacher has it. Hence, it is suggested in the studies presented that it would be useful to use the concept of proto-TPACK (see in Figure 9) to offer a more nuanced perspective on pre-service teachers' TPACK and its development. The concept of proto-TPACK was formulated first in Study I and the description was enriched in Studies II and III. In what follows, the different constructs of proto-TPACK, especially TK, PK, and TPK, are examined through the results obtained from the studies in this dissertation along with an explanation of the idea of proto-TPACK.

5.1 PROTO-TPACK CONSTRUCTS IN THIS DISSERTATION

First, proto-TK is investigated. In Studies I and II, the proto-technological knowledge of pre-service teachers, and students' innovative ideas about technology use in education seemed to be poorly developed: they discussed mainly office-type applications and general uses of ICT. There were only a few examples of collaborative ICT tools like wikis, blogs and social software. In Study I, pre-service teachers discussed ICT on rather a superficial level. In Study II, students talked more specifically about technical features. The change can be attributed to their three years of experiences with the iPads during their upper secondary school as well during their free time. In Study III, because the technology used, Second Life, was much more specific, pre-service teachers were able to discuss actively its technological features despite challenges with the technology during the experiment. These results are in line with earlier research demonstrating variations in pre-service teachers' TK and that their level of TK needs to be improved (see Finger et al., 2010). The findings have implications for teacher education because TK is changing all the time due to developments in technology (Koehler & Mishra, 2008). Therefore, the capabilities pre-service teachers have in using ICTs cannot be taken for granted in teacher education because of the unsure knowledge base.

In terms of proto-PK, the results of this dissertation can be discussed from the point of view of Bereiter and Scardamalia's (1987) operational model of teaching. According to the results of Study I and II, pre-service teachers' pedagogical approaches to learning situations were mainly teacher-centred. Results in Study I suggest that pre-service teachers' proto-PK is at an early stage of development. In Study II, control

of the learning situation was seen differently: students hoped for more responsibility but questioned their own capability to handle it. In Study III, perhaps because of the nature of the experiment, pre-service teachers revealed more student-centred pedagogies. According to the research literature, the question of pre-service teachers' PK, and especially the matter of student-centred and teacher-guided views and approaches, is significant for the development of overall TPACK (see Gao et al., 2011).

In terms of proto-TPK, the results in the studies vary. The results in both Studies I and II suggest that pre-service teachers and upper secondary school students expect teachers to be in control of ICT use, which can be seen as a sign of limited development of their TPK. In Study I this might be due to the fact that pre-service teachers' own experiences of learning with technology are limited, i.e. the use of ICT during their school history is minimal. In Study II, this is not the case, because the students were able to use iPads through their three years of studies in upper secondary school. One reason for the teacher-centred opinions in Study II might be due to the fact that according to the data, teachers were typically transferring their old teaching approaches to the iPads, i.e. the teachers' TPK was at a 'traditional' level. Despite their teacher-centred opinions about responsibility with ICT, students in Study II were able to discuss learning with ICT in detail. In Study III, pre-service teachers were able to discuss affordances and constraints of SL for a learning situation, because the technology (SL) and pedagogy (Role play) in the experiment were more specific. Results of Study III suggest that this kind of experiment fosters pre-service teachers thinking about the use of ICT in education, i.e. it develops further their TPK. Koehler and Mishra (2008) found the skills of seeing affordances and constrains of ICT to be important in terms of pre-service teachers' and teachers' TPK. They also emphasise that the skills to go beyond the weaknesses in the technology to find ways of adjusting them for their own pedagogical purposes.

The studies provided less data about pre-service teachers' proto-CK, proto-PCK and proto-TCK. This might be due to the research framework: because the data were collected in the context of ICT use in education this may explain the relatively few mentions about a connection to content. In addition, especially in Studies I and II, the results addressed technology, pedagogy and content on a more general level. These, and especially content, were specified in more detail in Study III, but did not score more emphasis on proto-CK, proto-PCK and proto-TCK. The assumption is that loose content connections and difficulties in connecting with content issues might be typical for pre-service teachers' proto-TPACK. This is in line with the caution of Koehler and Mishra (2008), that TCK is the most neglected aspect of the knowledge areas in the TPACK framework.

In Studies I and II the research was more focused on general-level ICT use in education, the data in these studies did not cover content issues in great detail. Therefore, in Study I the results discuss especially the TPK of pre-service teachers. In Study III the fact that pre-service teachers emphasized the pedagogical idea of the experiment might show that their TPACK is undeveloped and therefore they do not have the courage or the skills to discover new ways to connect the knowledge areas of pedagogy, technology and content. In Study II, the results were more about students' TPK. There, students' strong emphasis on knowledge transfer instead of student-centred learning could be seen as a sign of their limited TPACK development or limited development of the TPACK of their teachers. The data showed that teaching is not meeting student's needs and teachers need to develop their TPACK. In order to develop the TPACK of students and teachers, both need pedagogical support.

5.2 THE CONCEPT OF PROTO-TPACK IN DESCRIBING PRE-SERVICE TEACHERS' TPACK

Next, the idea and Figure 9 of proto-TPACK are presented.

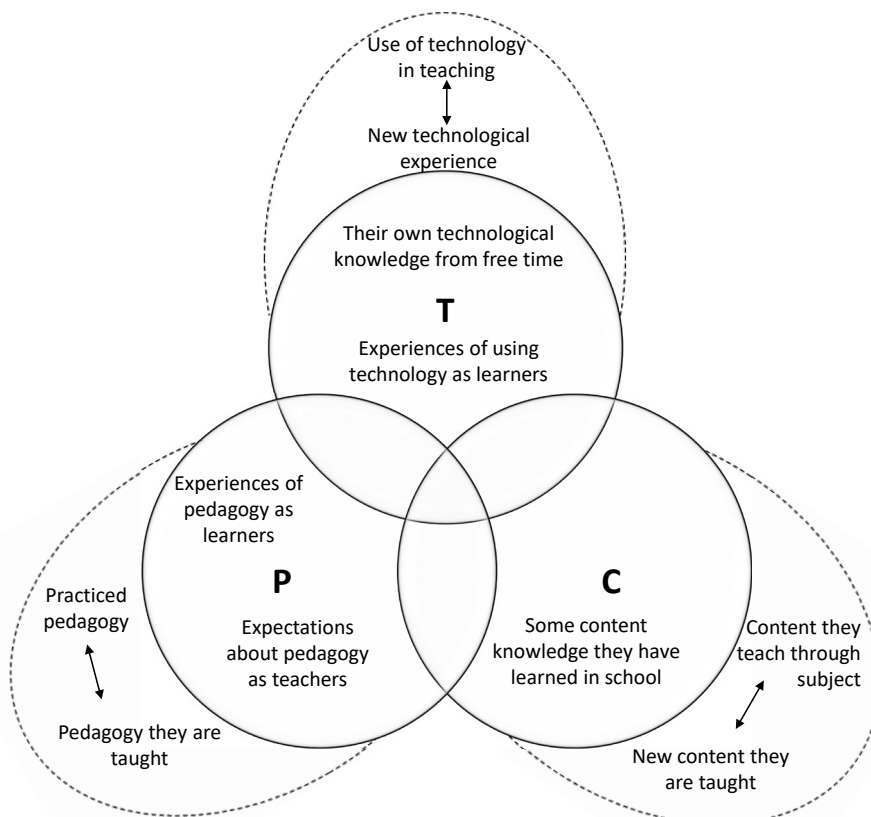


Figure 9. Proto-TPACK.

Pre-service teachers' previous experiences of technology, pedagogy and content as learners before teacher education create the basis for their proto-TPACK (inner circles in Figure 9). In addition, experiences from free time have effects on TPACK. Especially, technology use during free time influences nearly all people today and especially the young. These early experiences of technology, pedagogy and content impact on pre-service teachers' expectations of themselves as teachers. They are important to keep in mind because, according to Özcün-Koca et al. (2009/2010), the development of TPACK is connected to their identities as they make the transition from learner to teacher. Moreover, Wall (2016) argues that learning to teach is a constructive process that commences long before the individual begins a teacher education program. According to the research presented in this dissertation, especially Studies I and II, the basis for pre-service teachers' proto-TPACK is fragile.

In practice, development of proto-TPACK begins in teacher education (outer circles in Figure 9). During their studies in teacher training, pre-service teachers gain experiences from courses, where university teachers and lecturers model learning situations and organisation in school. University teacher are also a practical example to them.

Pre-service teachers' observations during teacher education (i.e. what they see other teachers and university lecturers doing) affect their planning and assessment of learning activities with and without ICT and the development of their TPK and TPACK skills (Hofer & Harris, 2010; Meagher et al., 2011; Polly et al., 2010; Özcün-Koca et al., 2009/2010;). Additionally, pre-service teachers get the possibility to see different kinds of teachers during their practice periods. According to Özcün-Koca et al. (2009/2010), pre-service teachers need to experience exemplary use of advanced technologies in classroom situations to understand the possibilities of the technology. All in all, experiences during teacher studies further develop preservice teachers' proto-TPACK. Study III concentrates on these areas.

The experiment in Study III and all the data collection methods in this dissertation had a two-fold purpose. The experiment, texts, empathy-based stories and reflective group conversations were ways to gain information about pre-service teachers' and upper secondary school students' knowledge of ICT-use in education for the purpose of the research. This information is very important for teacher educators who are planning and implementing teacher education. But also, the experiment and tasks suggested in this dissertation could have an important role for pre-service teachers in connecting previous experiences with experiences during teacher education to help them see the connections between the knowledge constructs in the proto-TPACK frame (see the intersections of outer and inner circles in Figure 9). Especially, the experiment with Second Life in Study III was a way to connect knowledge constructs of TPACK meaningfully and to help pre-service teachers model how to use ICT in education. A discussion about the implications for teacher education of these and the operationalisation of the proto-TPACK model are presented in section 6.2.

6 DISCUSSION

The TPACK framework is a widely used model for investigating teachers' and pre-service teachers' professional knowledge related to ICT use for teaching and learning. Its origins are especially in educational sciences and teacher education and therefore it is framework appropriate for use in this dissertation. TPACK is actively used as a theoretical framework with both qualitative and quantitative methods. This dissertation focused mainly on qualitative data and methods of analysis, introducing and using in TPACK research new methods, empathy-based stories and reflective group discussions.

The main aim of the studies in this dissertation was to provide insights into the starting points of pre-service teachers' TPACK, its development, and the factors influencing the development. Overall, results in this dissertation reveal an insecure foundation from which pre-service teachers start to build their TPACK. Their knowledge of TPACK constructs varies and in many cases is very limited. The results show how demanding TPACK is to pre-service teachers but also their readiness to extend their understanding and develop professionally useful skills. The attraction of modelling exemplary use of ICT and experiences of pedagogically justified ICT use is strong.

To help pre-service teachers in developing expertise in connecting technology, pedagogy and content in their teaching, there is a need for consistent and coordinated models in teacher education. The concept of proto-TPACK, developed theoretically and practically through this dissertation process, offers a more nuanced perspective on pre-service teachers' TPACK and its development. In this section, I will first discuss the main findings and their theoretical and practical implications. Then methodological considerations on this dissertation will be offered according to Yardley's (2008) criteria for validity of qualitative research, and finally I will turn to possible future studies.

6.1 CHALLENGES IN DEVELOPING PRE-SERVICE TEACHERS' PROTO-TPACK

A critique of the TPACK framework and associated research, and the challenges they present have been discussed in section 2.6. These critiques and challenges were acknowledged in the individual published papers that comprise the core of this dissertation and were taken into account during the research process and in design of the research frames (see section 3.2). The qualitative methods of data collection and analysis chosen were designed to answer to both the criticism that earlier TPACK research was too reliant on self-assessment of pre-determined scales (Voogt et al., 2013) and the challenge of defining knowledge constructs of TPACK. The research data i.e. texts, empathy-based stories and reflective discussion have deepened the understanding of TPACK constructs especially from the point of view of pre-service teachers. The challenges of defining boundaries and distinguishing adjacent constructs were also confronted. In Study I, the aim was to discover the situation at the beginning of the development of pre-service teachers' TPACK. According to the data, there is little evidence of more than basic mentions of CK and other TPACK constructs connections with content. In extending the investigation, in Study III pre-service teachers took part

in an experiment with a specific content (sex education), pedagogy (role play) and technology (Second Life) in order to help concretise different knowledge constructs. In addition, earlier research has acknowledged only a little variation in TPACK among different teacher groups and individuals. This dissertation brings to the fore early phase pre-service teachers and their developing TPACK. With qualitative methods and emphasis on the pre-service teachers' own voice, the variation among them was revealed.

Earlier studies have also shown unique challenges in developing TPACK in pre-service teachers who begin with a minimal level of all the TPACK constructs (see Koehler et al., 2014). In this research this minimal level is evidenced especially as the minor role of innovative uses of technology, preference for views of teacher-centred pedagogy, few mentions of content, and difficulties in connecting technology, pedagogy and, especially, content. There was also variation among pre-service teachers' knowledge in different TPACK constructs. To address these matters, the concept of proto-TPACK was introduced during the research for this dissertation to offer a more nuanced perspective on preservice teachers' TPACK and its development. Next, the findings of this dissertation are discussed according to different knowledge constructs of proto-TPACK.

Technological knowledge is an interesting area because of views about existing students belonging to the Net Generation, with the assumption that their skills with technology are strong, and rapid changes in technology. Recent research has questioned the Net Generation assumption (Finger et al., 2010; Lei, 2009; Valtonen et al., 2011). The results of this research show that pre-service teachers' proto-TK is not so strong; there is wide variation and it is lacking in innovative ideas for ICT use. This is of concern: Özcün-Koca et al. (2009/2010) claims that the lack of TK affects teachers' subsequent use of technology. Understanding the limitations of pre-service teachers' proto-TK is important from the point of view of teacher education, i.e. to note that these limitations might exist and to pay attention to the development of this knowledge area in teacher education programs. It would be useful to audit knowledge of technology at the starting point of the teacher education of pre-service teachers instead of assuming that their knowledge and skills are satisfactory.

Technology and ways technologies can be used for supporting learning are in a constant state of flux. Therefore, the technological knowledge of teachers and pre-service teachers is never "ready", i.e. it needs to develop continuously (Koehler & Mishra, 2008) and "evolve" with changes in technology. While the data in this research shows the limited proto-TK of pre-service teachers at the beginning of their studies, and at the end of upper secondary school studies, it is an area that needs to be given serious consideration in teacher education. Without this, the gap between pre-service teachers who can and cannot use ICT will become increasingly problematic, especially for individuals with limited TK. In addition to knowledge of current technologies, teacher educators need to awaken pre-service teachers' interest in following ICT developments and give them tools to adapt their knowledge "beyond" current technology. The ability to see the potential of new technological tools, ways to solve problems with them, and how to modify existing technology to their needs are crucial skills in the development of TK, TPK and TPACK (see Mishra & Koehler, 2006).

From the point of view of proto-TK, in Studies I and II, data revealed quite a number of teacher-guided pedagogies (see Bereiter and Scardamalia, 1987) and generally, students, pre-service teachers and teachers favour these pedagogies. These results are challenging from the point of view of the overall development of TPACK

especially given Chai et al. (2010) and Gao et al. (2011) observations on teachers' PK and the extent to which they see learning as a student-centred or a teacher-guided action. According to Wall (2016), pre-service teachers' PK is strongly based on their previous learning experiences in school. In the experiment conducted in Study III, the pedagogical approach was a student-centred role play and perhaps therefore the results of this study revealed more of the student-centred pedagogical knowledge of the pre-service teachers. These findings suggest that while the experiences from school might not be so student-centred, pre-service teachers need support for changing their pedagogical knowledge and aligning it more towards student-centred approaches. In practice, this would mean modelling student-centred pedagogies in their teacher training courses like in the experiment in Study III, and possibility observations of practicing teachers using these kinds of pedagogies. In addition, giving support to student-centred pedagogies to practicing teachers is important.

In all of the studies of this dissertation, there was little evidence of proto-TCK i.e. connecting technology to the development of knowledge constructs in specific subject areas. This aligns with Koehler and Mishra's (2008) notion that TCK is the most neglected aspect of the knowledge area in the TPACK framework. Additionally, proto-CK was not so well-present in the data, even though it was emphasised more in Study III (sex education). These results indicate that proto-TCK is an especially difficult area for pre-service teachers to engage with and therefore they also need support for this, i.e. support for connecting content to technology and matching suitable technologies to content. TCK is also a difficult area for schools, since content-specific equipment is expensive and teachers require up-to-date knowledge of both content and the technology that might support it. The lack of proto-CK in the study results might to some extent be due to the context which the research was conducted, where the tasks in first two investigations (Studies I and II) were not subject specific. In Study III, the assignment encouraged consideration of the content only at a general level. However, these limitations should not detract from the real challenges associated with proto-TCK development and ongoing TCK competences.

6.2 PRACTICAL AND THEORETICAL CONSIDERATIONS TO IMPROVE PRE-SERVICE TEACHERS' PROTO-TPACK DEVELOPMENT

Typically, the TPACK framework does not acknowledge differences between pre-service teachers' and teachers' TPACK, nor variation among teacher groups. It is suggested in this dissertation to recognise and take account of the earlier mentioned uncertainty and variation in TPACK as a starting point in teacher education and not to try to compare pre-service teachers' TPACK to that of experienced teachers. To this end, pre-service teachers' TPACK is described here with the help of the proto-TPACK framework (cf. Figure 9). Proto-TPACK acknowledges the challenges in technology integration of pre-service teachers but can also be used as a tool for pre-service teachers and teacher educators to identify gaps in their knowledge and help fill those gaps.

6.2.1 Transformative and integrative views on proto-TPACK

As discussed earlier in the theory section (2.4) of this dissertation, there are differing views about which areas of TPACK should be developed and in which sequence (e.g. Chai et al., 2011; Finger et al., 2010; Hofer & Harris, 2010; Meagher et al., 2011; Pamuk, 2011; Polly et al., 2010; Özcün-Koca et al., 2009/2010). How the TPACK framework is understood affects the planning and content of teacher education with regard to developing of proto-TPACK. In addressing these matters, there are two models of TPACK, which could be positioned at the ends of a continuum, at one end the transformative view and at the other the integrative view.

The transformative view (see Angeli & Valanides, 2009) means that TPACK is seen as a distinct body of knowledge, which can be developed on its own. From the point of view of teacher education this means that proto-TPACK should be developed and assessed so that all the aspects of the TPACK constructs are present. Hence, experiments similar to Study III, would be a way to develop preservice proto-TPACK. This approach may be open to criticism as being too overwhelming for preservice teachers to handle (see Koehler et al., 2014; Mouza, 2016). However, the results of our studies, especially Study III, do not support this criticism; our students were quite proficient at finding connections between constructs and therefore we believe the approach to be transferable.

The integrative view (Koehler and Mishra, 2005), suggests that TPACK develops from the three knowledge areas and their intersection. From the point of view of teacher education this means that also, for example, learning of pedagogy without connection to technology affects pre-service teachers' proto-TPACK. It would be ideal if everything learned in teacher education would affect positively the development of proto-TPACK. Reflective tasks or discussions, empathy-based method or writing tasks used in this dissertation might assist in finding connections between different knowledge areas of proto-TPACK.

Gess-Newsome (1999) noted with the PCK framework that not all of the researchers identified themselves with either transformative or integrative views, but located themselves somewhere on a continuum between the two. This was also the case with the proto-TPACK framework in this dissertation. It is important, therefore, to have both these overall experiences with ICT: in specific content areas with relevant pedagogies, (i.e. transformative) and stand-alone courses for pedagogy, technology and content, supported with reflective tasks or discussions (i.e. integrative).

Chai et al. (2010) noticed that pre-service teachers might have difficulties in separating the areas of TPACK from each other, because of the limited amount of their studies and teaching experience. There are naturally individual differences with this. For example, some pre-service teachers might accept certain pedagogical approaches but struggle with technology integration. Some students on the other hand may be quite open to new approaches and find it easy to connect different knowledge constructs. According to Pöntinen (2013), it is important to promote in teacher education the educational use of technology as a natural part of teaching and learning.

6.2.2 Developing proto-TPACK to a “mature” TPACK

As described in the theory section of this dissertation, there are several different paths to developing TPACK (See section 2.6, Figure 2). Ideas emerging from this disserta-

tion for fruitful ways to develop proto-TPACK towards mature TPACK are shown in figure 10. On the left-hand side of the diagram are ways of developing pre-service teachers' TPACK as suggested by the research literature. These have been discussed in fully in section 2.5.2 and were originally shown in Figure 2. The right-hand side of the diagram shows ways of developing a more mature TPACK as suggested by the research reported in this dissertation. The two sections are connected with a broken arrow indicating the developmental nature of the progression through meaningful learning with technology. Meaningful learning refers in this dissertation (see Figure 10) to learning that is focused on making connections between different constructs of the TPACK frame through systematically consolidated experiences. This consolidation happens through applying technology to pedagogical practice in their general educational courses throughout teacher education. Modelling and reflection on experiences are key elements in the development process. Modelling helps pre-service teachers see the connections between the different constructs. Reflection on experiences is important in bringing these constructs together into a developing maturity with TPACK and increasing professional confidence. In the development of the more mature TPACK, the expanding understanding of PCK and TPK become integrated in the overall framework for TPACK.

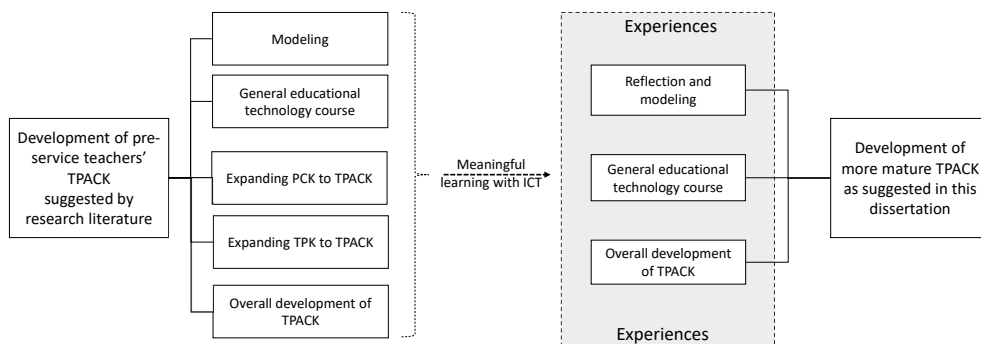


Figure 10. Development of pre-service teachers' TPACK.

As was noted in section 2.5.2, PCK and TPK develop as pre-service teachers become more experienced and confident with their use of technology in teaching. This experience and confidence can come from all parts of their pre-service teaching education, but general educational technology course would help them consolidate. Next, the impact of previous experiences and meaningful learning with technology for pre-service teachers' development of proto-TPACK are discussed in the light of the results of this dissertation and earlier studies.

The research from this dissertation suggests that previous experiences are a key to reflection of ICT use in education. Especially in Study I and II, but also in Study III, pre-service teachers' and students' experiences as learners were important in their proto-TPACK. This aligns with notions of Özcün-Koca et al. (2009/2010) that pre-service teachers' development of TPACK is connected with their shift from learners to teachers. It seems that in the beginning of their studies prior experiences as learners in school (Studies I and II) but also their experiences as learners in teacher education (Study III) are significant for the development of their proto-TPACK. For this reason, it

would be important to discover something of their school experiences during teacher education and reflect and build on them. Methods like reflective group discussions, writing tasks, open-ended questioning, or empathy-based stories would be good ways to start reflection on experiences. These experiences should be taken as the starting point for their proto-TPACK development. In this way, proto-TPACK would become a tool for analysing experiences deeply as a foundation for further development. Pre-service teachers could acknowledge their experiences and concretise them relative to their developing TPACK by positioning them in the proto-TPACK diagram (see Figure 9).

Not only previous experiences, but also meaningful learning with technology, are paths to developing pre-service teachers' TPACK. As the results from Study II show, it is not enough only to have technology available for students during upper secondary school, but also to have pedagogically meaningful learning with technology. Current curriculum changes in Finland include an increasing role for ICT as a tool and environment for learning and communication with strong emphasis on collaborative and inquiry-based learning methods (cf. Finnish National Board of Education 2014). This aligns well with the student-centred approach of Bereiter and Scardamalia (1987) and will hopefully affect these experiences by giving teachers possibilities to use technologies in more meaningful ways. It is also important to pay attention to the support required for teachers to learn meaningful ways to use ICT. The Study II results, which align with earlier studies (see Cochrane, Narayan & Oldfield, 2013; Ifenthaler & Schweinbenz, 2013), show teachers mainly transferring their old approaches to new devices. Supporting teachers to find meaningful ways to use ICT in learning is also a very important topic for the in-service training of teachers when they are working professionally in schools.

While the results suggest that learning experiences with technology in teacher education are important, it is desirable to offer these experiences to pre-service teachers, i.e. model how to use ICT with certain content and pedagogy as we did in Study III. These experiences should be discussed and reflected on to deepen understanding and to connect different aspects of learning situations according to the proto-TPACK framework. According to Tondeur, Roblin, Braak, Voogt and Prestridge (2017), teacher educators' uses of technology during the course are important models and motivations for pre-service teachers to use ICT in their own teaching. In addition, aligning with Angeli and Valanides' (2009) transformative view of TPACK development, pre-service teachers' studies of multidisciplinary subjects should include exemplary teaching to provide well-designed positive experiences for them.

Figure 11 shows the proto-TPACK tool proposed as an outcome of this research. The diagram is read from top to bottom and left to right, starting from beginning phase of teacher training, moving through their professional development and ending with their continuing in-service training as practicing teachers. The three boxes represent actions that should be undertaken in each of the major stages of development. The first box at the top of the diagram shows the importance of making visible the relations between ICT, pedagogy and content in all courses. The middle box suggests that there should be reflection activities that help student to make connections between TPACK constructs. The third box at the bottom of the diagram shows, how these connections are consolidated and concretized through reflective assignments, which help students to recognise their strengths and weaknesses in understanding and applying TPACK.

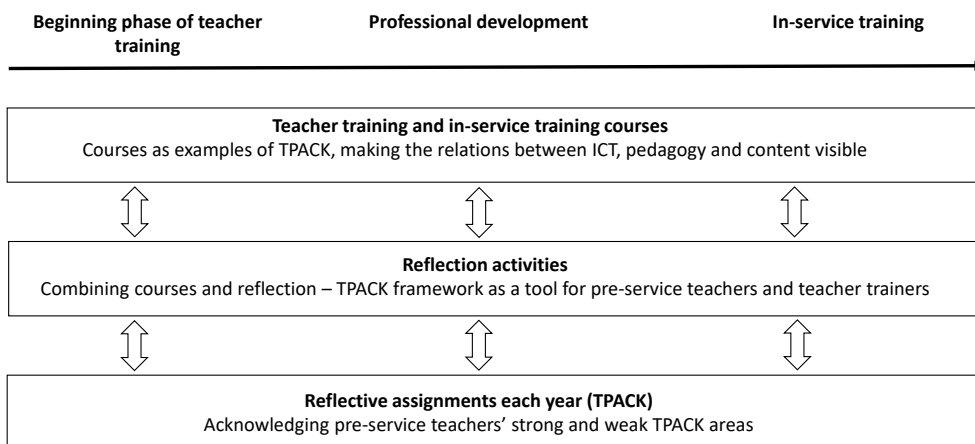


Figure 11. Proto-TPACK tool.

According to our studies, earlier experiences with technology in education seem to differ a lot and therefore provide a variable basis for proto-TPACK. Therefore, it is suggested from Study I that the level of pre-service teachers' proto-TPACK should be audited in the beginning of and during their studies and these findings should be taken into account in teacher education programmes. This audit could be done by pre-service teachers themselves and should be followed-up during the studies. The proto-TPACK framework forms a good basis for this audit. Connecting earlier experiences with new, meaningful learning experiences with ICT and modelling exemplary use of ICT in teacher education, will help pre-service teachers reflect on ICT use in education. Auditing of knowledge should be a continuous practice during teachers' education, where the proto-TPACK model provides the basis of a tool.

Aligning with an integrative model of TPACK, independent course contents of pedagogy, technology or content could also be used for developing pre-service teachers' TPACK. But to better see connections with pedagogy, content and technology, learning tasks and situations should be connected with reflection on different knowledge construct and their consolidation. This reflection and consolidation could be conducted with a task or in discussions as was shown in Studies I and III, and further developed by connecting the reflection to the proto-TPACK framework.

According to the data in this research, it also seems that for pre-service teachers and students it is difficult to discuss technology/ICT generally, but when the discussion is focused on a specific technology/tool (iPad, Second Life) it is more fruitful. It seems that it is helpful to have some prior experience on which to base discussions, making it a lot easier to talk and think about technology use in education. In these situations, identifying constraints seems to be easier for pre-service teachers than seeing advances of technologies. Strong attitudes against technology use in general and in education might be part of the problem. Pöntinen, Dillon and Väisänen (2015) also point out that accepting uncertainty as a part of the learning process is often uncomfortable for pre-service teachers. In the bigger picture this is also about how we see effective learning in school. Is learning something that goes smoothly without problems or do we see that confronting difficulties and problems might be helpful learning experiences? We need to encourage students to take risks, i.e. dare to try new technologies even though

there is a possibility they might not be successful or have limited success. This kind of attitude would help them to follow-up on the development of technology and to see its potential. These kinds of skills are acknowledged by Koehler and Mishra (2008). We should encourage pre-service teachers to be innovators in their future teaching by challenging them during their studies to do things at the limits of their abilities/skills, and to be open to the possibilities offered by the technology.

Findings concerning proto-TPACK suggest that it should be used as a tool for reflection and development in teacher education and in continuing professional education by showing the relevance of TPACK knowledge constructs in courses such as teacher pedagogical studies. The starting point in every action and development of proto-TPACK should be earlier experiences, personal strengths and possibilities. These could be opened up with locating them in a proto-TPACK frame/figure/tool, i.e. what are pre-service teachers' and teachers' experiences, strengths, possibilities, etc., of technology, pedagogy, content, TPK, TCK, PCK and TPACK. From these, pre-service teachers should be encouraged to think about their goals, the ways they might achieve them, and the support required for them. Along with this, there should be a tool for teacher educators to support students' development and to encourage teacher educators to consider themes and courses in teacher education from the point of view of proto-TPACK. To achieve this, more research on teacher educators' TPACK is needed. Earlier TPACK research has not so much addressed defining the target level of TPACK. Should we really define exact goals for TPACK or could we even do so? With the technology changing all the time and pedagogical and content area knowledge evolving, the desired level of TPACK will be constantly changing. It is a moving target. A new technology rush into schools, like tablet computers a few years ago, might create challenges for teachers as was described in Study II. For individual teachers, proper TPACK might also mean different things and its continual development and updating could be seen as a lifelong process like learning. As the visualisation of TPACK is a Venn diagram with equal-sized circles, the ideal situation might be that the different knowledge areas of teachers are somewhat in balance. Acknowledging personal strengths and weaknesses in different knowledge areas with the help of the TPACK framework would be a good way to maintain balance. However, when we talk about balanced TPACK, in practice this seldom means equal weighting of each of the constructs, but rather where all of the TPACK constructs are represented in the learning activities. In this way teachers come to understand the important contribution that each of the constructs makes to the learning activity both individually and in combination.

6.3 METHODOLOGICAL REFLECTION

While this dissertation includes mainly qualitative research, there are no one generally approved criterion for considering its validity/reliability. For gaining an overview of the validity of this dissertation, I use here Yardley's (2008) criteria for validity of qualitative research. Yardley's criteria consist of four main points for viewing validity: sensitivity to context, commitment and rigour, coherence and transparency, and impact and importance. Next, I discuss the three studies of this dissertation from these points of view. At the end, I point out some limitations concerning this dissertation.

Part of sensitivity to context according to Yardley (2008) is that a researcher presents relevant theoretical and empirical literature. In this dissertation, this is done in the theory section (2 Theoretical framework), where previous TPACK research and

the gaps in this research are discussed, and the framework is critiqued. In addition, other relevant theories related to technology integration in education are explored. In the method section the methods adopted are explained and justified with reference to relevant literature. Taking account of socio-cultural settings is important from the point of view of sensitivity to context. This means that the possible impact of the characteristics of the researchers and data collection settings on participants are covered (Yardley, 2008). According to Cohen et al. (2007), open-ended questions encourage participants to respond freely and talk about what is important. Open-ended questions were used in Study I. Also, the empathy-based method, used in Studies II and III, allows participants to write freely about their views of the topic (Eskola, 1998). On the one hand, it was decided not use moderators in reflective discussions to avoid their impact on the data collection in Studies II and III. On the other hand, with the help of moderators, the discussion might have been more detailed and the risk of some students dominating the issues would have been reduced. Furthermore, the presence of a moderator as a member of university staff (in Study III) and unknown adult (in Study II) might have had some effect on the atmosphere of discussions. Sensitivity to data was addressed in analysis. Even though the categories and themes were pre-decided because of theory-guided content analysis in Studies I and III and thematic analysis in Study II, open-coding was used in Study I and III to create subcategories and codes. Also in Study II, the codes and divisions arose from the data.

Ethical issues are an important part of context sensitivity. The studies in this dissertation followed the ethical guidelines of the Finnish National Advisory Board on Research Ethics (2009). Participants in this dissertation were all aware of data collection and they were willing to participate. There was also a possibility to decline participation in the research. The names of the informants are not presented in the study reports and individuals cannot be recognised. Especially in Studies I and III, data collection was also part of the pre-service teachers' learning process, so participation in the research did not take any extra-time from them. In Study II, the data collection was organized during the school day for this reason.

The second point of view of validity according to Yardley (2008) is commitment and rigour. This means that the researcher introduces, through broad and deep analysis, enough additional insight into the researched topic. First of all, in this dissertation the focus of TPACK was especially on its early development, i.e. before and in the early stages of teacher training. Although this is qualitative research, the amount of data was quite large, especially in Studies I and II; the whole cohort of that particular year of students. In Study III, all the participants in the course were part of the study. This could be treated as a mark of engagement and precision in data collection. Hofer and Grandgenett (2012) mention that examining pre-service teachers' reflections connected to the TPACK framework offers information about their rationale for instructional decisions and glimpses of their thought processes. From this perspective, this dissertation brings additional insight into TPACK research, because all the data consist of participant reflections of their experiences with ICT use in education.

Depth of analysis and methodological skills are mentioned as a sign of commitment and rigour. While all the studies were categorized as qualitative analysis, skills with these kinds of analysis methods were developed throughout the dissertation process. Analyst triangulation was used in Studies I and II to gain validity/reliability. In Study III, the support of research group negotiations during the analysis process was important. In Study I, the data was partly coded by another trained research assistant and a measure of agreement was calculated. After the second round of coding

the measure of agreement was over 90 percent. According to Miles and Huberman (1994), the coding is valid when the measure of agreement is over 80 percent. In Study II, the analyses were done by two researchers who negotiated shared understandings and resolved ambiguities through discussion.

In addition to analyst triangulation, there was also triangulation of data collection methods in Studies II and III. Both studies had two kinds of data, empathy-based stories and reflective group discussions. With the help of different data, the picture of the research area became richer. Also, the similarities between the data assured the results while similar content was able to be found from different data sources. Even though the target groups of each study were different, similar themes, attitudes, etc., could be found from different data and studies.

Atlas-ti software was used in handling the data for all of the studies. It was used in quantification of data but also with grouping of codes and finding certain sub-categories, sub-themes, categories and themes. It also helped with finding descriptive quotations from the data to describe certain themes and categories of analysis.

The third point of view of validity in Yardley's (2008) criteria is coherence and transparency, which means how research makes sense as a consistent whole. One part of this is transparent methods and data presentation. In the studies reported here, this was achieved by including illustrative quotations from the participants in support of categories and themes that emerged from the data. Also, different tables and figures are presented on the analysis process and category building.

The chosen analysis methods of this dissertation, qualitative theory-guided content analysis and qualitative thematic analysis, are both considered as flexible methods but also criticised for being too simple or "superficial" (see Cohen et al., 2007; Elo & Kyngäs, 2008; Guest et al., 2012). Flexibility of methods also brought about some challenges to the research, because there were no certain simple procedures to follow during the analysis. These challenges were answered with detailed explanations and illustrations of analysis. The collected data was large enough and diverse enough to overcome possible weaknesses of analysis methods and to compose a comprehensive view of preservice teachers' proto-TPACK.

Reflexivity is part of coherence and transparency. It means that a researcher opens up their own relationship with the topic, the participants and the data. When looking at pre-service teachers' experiences of ICT in education, I have to recognise my own experiences of ICT in education as a former pre-service teacher and teacher, and my present experiences of it as a teacher educator. I have a positive view of ICT in education. I see the value and importance of it for students learning, motivation and skills and therefore see its importance for pre-service teachers. These things affect my motivation to conduct the research and to develop further the tools for teacher education.

Yardley's fourth point of view to validity of research is impact and importance, i.e. how research findings might have practical, theoretical and socio-cultural impacts. The TPACK framework has been considered as "unsure foundation" (see Graham, 2011). By exploring the beginning phase of TPACK development, this dissertation helps to describe theoretically and practically the base of TPACK. The developed proto-TPACK model has both practical and theoretical impact. Theoretically it develops TPACK research especially pre-service teachers' knowledge from a qualitative point of view and provides a framework to analyse pre-service teachers' knowledge. The concept of proto-TPACK offers more nuanced perspective on pre-service teachers' TPACK and its development. Practically it is developing teacher education by providing it with a tool for assessing different courses and a framework for development

in a coordinated way. The introduction of new methods (the empathy-based method) into TPACK research is one of the contribution to knowledge made through this dissertation.

Part of validity is to acknowledge the possible limitations of the research. In this dissertation, as with all research, there are some limitations to note. First, the research framework was set up in studies so that students and pre-service teachers concentrated more on their answers/replies in the school-context rather than in the context of their free time. In future, the assignments should be set up so that also the view of free time is acknowledged, because learning in informal settings is becoming an increasingly important aspect for people in the digital age. Second, the difficulty for pre-service teachers to open up content and technological content aspects in their answers would require different kinds of assignments and methods. The questions and assignments should be addressed differently concentrating deeply on content and technological content knowledge. It might also be good to provide resources (or internet connection) connected to content. Third, it is important to note that studies of this dissertation concentrates especially on the beginning phase of teacher education and therefore it gives knowledge of the early stage development of TPACK, indicating that from the perspective of more experienced pre-service teachers, the results need to be considered with caution. Altogether, the results align well and continues the previous research concerning the pre-service teachers' developing TPACK indicating that results gained should be transferable to early phase of teacher education. Especially within Finland, the results can be seen as transferable because of the similarity within teacher education contexts. In addition, results gained focuses strongly on pre-service teacher's TPACK from the perspective of pedagogical knowledge. This suggest that results are not relying on quickly developing technology i.e. they can be seen current and applicable for a longer period of time.

6.4 FUTURE STUDIES

Many possible lines of future enquiry have already been suggested in earlier parts of this conclusion, especially in section 6.2 with respect to the proposed proto-TPACK tool.

The proto-TPACK tool suggested in this dissertation has some utility, but it could be refined with further research. It would be interesting to take the tool into coordinated use in teacher education or in supplementary education in in-service teacher training. For example, action research tracking the process of using the proto-TPACK tool would provide avenues to further develop and refine it. To provide a holistic view of the efficiency of the proto-TPACK tool, longitudinal research following preservice teachers from the beginning of their studies to their early years in the profession is also desirable. In addition, as the proto-TPACK tool is connected mainly to TPACK research, later it should be considered from the point of view of general pre-service teachers' professional development research (see Väisänen & Silkelä, 2000).

Research in this dissertation concentrated especially on the beginning phase of studies of pre-service teachers. Therefore, it would be interesting to examine the development of proto-TPACK in the later phases of their studies. The data in this dissertation were collected from the teacher training courses without connection to "real pupils" and the teaching circumstances associated with them. Later, it would be interesting to study how the teaching practice periods affect pre-service teachers'

proto-TPACK in cases where practicing teachers model ICT integration in classes. In addition, pre-service teachers' own teaching with ICT would be worth examining. With the help of these studies, the earlier mentioned proto-TPACK tool for reflection could be also further developed and refined. As mentioned earlier, teacher educators' TPACK should be examined in more detail in order to find ways to support them in integrating technology into education.

Earlier research has seldom discussed the variation in the skills of teachers in different TPACK areas, but there are some preliminary results which give indications that differences exist (see Valtonen et al., 2018). In addition, this dissertation's results acknowledge differences among pre-service teachers. Therefore, examining the different levels and "types" of TPACK of pre-service teachers and benefiting from them are matters for further investigation.

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SINI KONTKANEN

This dissertation focuses on pre-service teachers and upper secondary school students as users of ICT in education from the point of view of the TPACK framework. Results encourage the suggestion that pre-service teachers should be evaluated through a 'proto-TPACK framework'. This dissertation presents ideas for developing teacher education using the proto-TPACK framework based on results from earlier studies as well as results from the three studies in the dissertation.



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