Nordic Journal of Digital Literacy

Universitetsforlaget

RESEARCH PUBLICATION

Volume 17, No. 1-2022, p. 61–74
ISSN online: 1891-943X
DOI: https://doi.org/10.18261/njdl.17.1.5

Professional digital competence in initial teacher education: An examination of differences in two cohorts of pre-service teachers

Johan Kristian Andreasen
Associate professor, Department of Education, University of Agder
Johan.k.andreasen@uia.no

Cathrine E. Tømte
Professor, Department of Education, University of Agder

Ingvild Bergan
Assistant professor, Department of Education, University of Agder

Velibor Bobo Kovac
Professor, Department of Education, University of Agder

Abstract
Initial teacher education plays a vital role in preparing pre-service teachers (PSTs) to integrate technology into their classroom practice. In the present study, we examine how PSTs perceive their professional digital competence (PDC) in the context of a major teacher education reform in Norway. Survey data was collected from two cohorts, consisting of primary and lower secondary PSTs, both before (cohort 1) and after (cohort 2) the teacher education reform. Several theoretical concepts were selected to operationalize PDC, including technological pedagogical knowledge, confidence in the use of ICT, ICT self-efficacy, perceived usefulness, and ICT and inclusion. The overall results show a significant increase in the pre-service teachers' professional digital competence in cohort 2. The findings indicate that partnership initiatives between university faculty staff and school-based mentor teachers are associated with the pre-service teachers' development of PDC. Several development initiatives in initial teacher education that are relevant to other higher education institutions are also discussed.

Sammendrag
Lærerutdanningene spiller en sentral rolle i å forberede lærerstudentene til å integrere teknologi i sin klasseromspraksis. I denne studien undersøker vi hvordan lærerstudenter vurderer sin profesjonsfaglige digitale kompetanse (PfDK) i lys av en større lærerutdanningsreform, og et utviklingsprosjekt finansiert av Kunnskapsdepartementet. Data ble samlet gjennom spørreskjema fra to kohorter grunnskolelærerstudenter (GLU 1-7 og GLU 5-10), før (kohort 1) og etter (kohort 2) lærerutdanningsreformen. For å operasjonalisere PfDK benyttet vi flere teoretiske begrep, slik som teknologisk pedagogisk kunnskap, selvtillit i bruk av teknologi, mestringstro, erfart nytte og IKT og inkludering. Resultatene viser en signifikant økning i lærerstudentenes PfDK i kohort 2. Funnene indikerer at nye former for partnerskap mellom lærerutdannere på universitetet og i skolen kan assosieres med lærerstudentenes utvikling av PfDK. Studien inkluderer en diskusjon av flere utviklingstiltak i lærerutdanningene som kan være relevant for andre høyere utdanningsinstitusjoner.

Keywords
Professional digital competence (PDC), initial teacher education (ITE), pre-service teachers (PSTs), partnership

Introduction

Through teacher education, pre-service teachers (PSTs) are expected to achieve proficiency as digitally competent teachers who can support their pupils' development of their own digital competence. Studies show that teachers in technology-enriched classrooms are better able to adapt their teaching to individual students' needs (e.g., Tømte et al., 2019). But increased digitalization in education also introduces challenges into daily school life, such as digital distractions, potential information insecurity, digital exclusion, and online bullying (Macaulay et al., 2018; Gudmundsdottir et al., 2020).

The numerous new opportunities and challenging side-effects of increased digitalization mean that teacher educators within higher educational institutions must be digitally competent to offer the necessary support to PSTs in terms of technological infrastructure and competence developments (Uerz et al., 2018). Policy-driven intentions and research demonstrate that this ambition develops more slowly than might be expected, since it is quite demanding for teacher education institutions to meet these expectations (Tondeur et al., 2018). Previous study findings have shown that newly qualified teachers often do not develop sufficient digital competence to utilize the possibilities for integration, and to critically evaluate the use of digital technologies in the classroom (Gudmundsdottir & Hatlevik, 2018; Tondeur et al., 2018). This demanding situation is undoubtedly not particular to Norway, and indeed may be observed across various educational systems in Europe (Uerz et al., 2018; Kelentrić et al., 2017). A gap thus currently exists between schools' needs for digitally competent teachers and the education that is offered in this area (Instefjord & Munthe, 2016). This background clearly shows a need for research-based knowledge about the role of teacher education programs in developing PSTs' professional digital competence (Gudmundsdottir & Hatlevik, 2018). The field particularly requires more quantitative studies, as most existing research is exploratory and qualitative in nature (Uerz et al., 2018).

To cope with these challenges, in 2018, the Norwegian government launched an initiative to provide funding to five of Norway's teacher education institutions to boost the PDC development of teacher educators and PSTs. Among these efforts was the ProDiG project ("professional digital competence in initial teacher education") at the University of Agder (UiA). A key objective was to provide pre-service teachers with adequate PDC for their future careers as schoolteachers. The ProDiG project thus serves as a background for the present study, where we investigate two cohorts of PSTs in initial teacher education and examine how they differ in relation to several selected theoretical concepts connected to their PDC. The present study is, to our knowledge, the first of its kind to measure pre-service teachers' PDC after Norway's major teacher education reform in 2017.

Teachers' professional digital competence

During the development of terminology related to teachers' PDC, the various concepts have gradually changed from the simple use of digital tools to the use of broader terms such as "digital competence" and "digital literacy" (e.g., Wilson et al., 2020). In this context, teachers are expected to be able to contribute to the development of students' digital competence and therefore be able to use technology in their teaching. PDC involves a broad range of knowledge to effectively operate in digital environments, including cognitive, emotional, and sociological knowledge (Røkenes & Krumsvik, 2016). Although PSTs have generally positive attitudes toward information and communications technology (ICT) for teaching and learning, they are nevertheless more reserved when integrating ICT into their classroom practices (e.g., Sadaf et al., 2012). Ertmer (1999) distinguishes between first and second-order barriers that can hinder these implementation efforts. Ertmer describes first-order

barriers as extrinsic, including lack of access to available technology, insufficient time, and inadequate support. Second-order barriers are the teachers' intrinsic beliefs about technology, teaching strategies, established classroom practices, and attitudes toward changing their practice. To circumvent these barriers, initial teacher education must promote teaching strategies that address both technical skills and incorporate meaningful uses of technology. Doing so requires practical hands-on training, both at campus and in school practicum, where students can design teaching activities that include digital technology (Tondeur et al., 2012; Røkenes & Krumsvik, 2016). Thus, modeling by skilled mentor teachers is typically emphasized, which in turn influences prospective PSTs' intentions to integrate technology (Nelson, 2017).

Based on previous studies that have examined teachers' and pre-service teachers' professional digital competence, in the present study we have included several variables that are expected to be related to pre-service teachers' PDC. The sections that follow describe these variables and provide a theoretical rationale for inclusion in the study.

Technological pedagogical knowledge (TPK)

Several scholars have suggested that the pedagogical use of ICT must be seen in the context of pedagogical, technological, and didactic areas (e.g., Mishra & Koehler, 2006). Mishra and Koehler (2006) define TPK as "knowledge of the existence, components, and capabilities of various technologies as they are used in educational settings, and conversely, knowing how teaching might change as the result of using particular technologies" (p. 1028). This knowledge is usually demonstrated by applying technology in pedagogical practices, and the use of technology to create authentic learning and assessment strategies. Thus, teachers need to develop a complex form of teacher knowledge that can integrate pedagogy with technology (Schmidt et al., 2009). The rationale for using TPK in the present study is based on research that has shown that this type of knowledge is positively related to teacher self-efficacy, perceived usefulness of technology, and teachers' intention to use technology (Abbitt, 2011). Studies have also shown that teachers with well-developed TPK are more likely to use technology appropriately and to be confident in their instruction (e.g., Maeng et al., 2013).

Confidence in the use of ICT (CU-ICT)

Several factors determine how teachers integrate ICT in their classrooms, including ICT experience, skills, and attitudes toward ICT (Hernández et al., 2014). Some contradictory findings, however, have indicated that technology skills and actual practice in the classroom are not always linked, which is the case among both PSTs (Negishi et al., 2003) and in-service teachers (Becker, 2000). This situation might be caused by teachers' lack of confidence in their own capabilities, which involves the teachers' perceived likelihood of succeeding in using ICT for educational purposes (Nikolopoulou & Gialamas, 2015). Thus, PSTs who develop confidence in technology integration in the classroom during initial teacher education (ITE) will also be more likely to integrate technology into their professional teaching practice (Al-Awidi & Alghazo, 2012).

ICT self-efficacy

Self-efficacy refers to people's belief in their ability to successfully accomplish specific tasks and to be persistent in the face of obstacles (Bandura, 1977). Based on accumulated theoretical and empirical evidence, teachers' self-efficacy beliefs can have a clear impact on their motivation, teaching, and performance, thus affecting students' learning (Tschannen-Moran & Johnson, 2011). Previous research has provided strong evidence that teachers' self-

efficacy beliefs about technology integration and best practices in classrooms are positively correlated (e.g., Albion, 1999). We must note, however, that enhanced self-efficacy beliefs do not automatically translate into actual technology use but have been found to be a useful indicator and a necessary condition for technology integration (Abbitt, 2011). Research suggests that teachers' self-efficacy beliefs promote enthusiasm for using technology in their instruction (e.g., Anderson et al., 2011). This finding is especially the case for PSTs or novice teachers, since self-efficacy beliefs have been shown to impact their actual practices more directly (Valtonen et al., 2015).

Perceived usefulness of ICT in teaching and learning (PU-ICT)

How PSTs perceive the usefulness of ICT in the classroom is part of their belief system (Delone & McLean, 2003) and refers to their individual beliefs about the benefits of using ICT to improve their job performance (Joo et al., 2018). Studies have found a clear connection between how PSTs assess the value of classroom technology integration and their intentions to use technology in their future classrooms (e.g., Teo, 2019). Several studies have also indicated a clear relationship between teachers' attitudes toward ICT integration and effective technology implementation in the classroom (e.g., Anderson et al., 2011).

ICT and inclusion

ICT has in recent decades played an increasingly important role as flexible tools to support learning processes and developing inclusive schools (e.g., Roy et al., 2013). The use of ICT allows teachers to differentiate their teaching to a diverse group of students by utilizing diverse student-active and creative approaches to teaching (Chauhan, 2017). Thus, digital technology can help provide all learners the ability to access the curriculum and may offer a variety of strategies to achieve certain learning objectives they might otherwise have difficulty achieving.

Digital judgment

In the current digital age of education, PSTs are expected to develop PDC to navigate the complexity of this increased digitalization. Such complexity is related to many challenging interpersonal situations, including online harassment and bullying, privacy issues, the evaluation of online content, and the proper use of information (Livingstone et al., 2015). An essential purpose of education in general is thus to raise a generation of digitally active citizens who will be responsible for addressing all these issues (Choi et al., 2018). One rationale for including the concept of digital judgment in the present study is based on research that has shown that PSTs do not acquire sufficient competence to address challenges related to ever-increasing digitalization (Macaulay et al., 2018).

Teacher educators' professional digital competence (TE-PDC)

Scholars and others have long questioned whether teacher educators are sufficiently inspiring role models, since teacher educators often do not use technology effectively enough themselves (Valtonen et al., 2015; Uerz et al., 2018). Studies have shown that even though more teacher educators use technology in their instruction, their instruction is insufficient for PSTs to use technology in the classroom (e.g., Kaufman, 2014). The teaching frequently seems to be characterized by a predominant focus on theoretical approaches to digital technology, thus failing to activate the PSTs through practical examples and engaging teaching strategies (Røkenes & Krumsvik, 2016). We have thus examined PSTs' assessment of the need for their campus teacher educators to develop PDC.

Research context: The ProDiG project at the University of Agder

In the context of a major teacher education reform in Norway (four-year bachelor's degree to a five-year master's degree), UiA initiated the three-year partnership project ProDiG (Professional Digital competence in initial teacher education) in cooperation with municipalities and schools in the region. The aim was to redesign the teacher education program and to strengthen PSTs' and teacher educators' professional digital competence. PDC were included in the subject syllabus and adapted to the practical training of PSTs at campus as well as at the partner schools. The ProDiG project included several efforts, such as a partnership initiative where school-based mentor teachers from partner schools were contracted as joint faculty members (20%) at the university, PDC workshops located in partner schools, the development of a new elective course (30 ECTS) on teachers' PDC and faculty training for teacher educators.

The present study's overall objective is to examine how two cohorts of PSTs perceive their PDC in the context of the national teacher education reform and the local redesign efforts initiated by the ProDiG project. Those PSTs who have enrolled in the reformed five-year master program (cohort 2) thus have been exposed to a wide range of digital learning initiatives at the university and partner schools. We conceptualize PDC in terms of six selected and previously introduced theoretical perspectives: *technological pedagogical knowledge* (TPK); *confidence in the use of ICT* (CU-ICT); *ICT self-efficacy*; *perceived usefulness of ICT in teaching and learning* (PU-ICT); *ICT and inclusion* and *digital judgment*. In addition, we seek to measure how the pre-service teachers perceive the need for competence development among their *teacher educators* (TE-PDC). Based on this starting point, we seek to test the following hypotheses:

1. We hypothesize a difference between cohort 1 and cohort 2 in the measures of pre-service teachers' PDC for technology integration in the classroom.
2. We hypothesize that differences between cohort 1 and cohort 2 have a specific direction; we expect that pre-service teachers in cohort 2 will have a higher PDC for technology integration in the classroom compared to participants in cohort 1.
3. Finally, we expect that participants in cohort 2 will have a lower assessment of the need for competence development in PDC for their university lecturers.

Methods

Sample and data

The participants in the present study were third-year PSTs enrolled in primary and lower secondary teacher education at the University of Agder. An online questionnaire was administered to cohort 1 in February 2018 and cohort 2 in February 2020. The two cohorts include PSTs before (cohort 1) and after (cohort 2) the teacher education reform in Norway (master's degree), including several implemented measures with the specific aim of strengthening the PDC of pre-service teachers and teacher educators.

The survey was made up of two sections: (1) demographic information and (2) questions about pre-service teachers' PDC and ICT usage in initial teacher education. The overall response rate was 73% (N = 128) in cohort 1 and 67% (N = 118) in cohort 2. Cohort 1 had a mean age of 22.9 (SD = 2.71) and 77% female, while cohort 2 had a mean age of 23.11 years (SD = 2.45) and 73% female. The data was collected and analyzed in line with normative ethical standards for researching in Norway, including approval from the Norwegian Social Science Data Services.

Measures

A questionnaire was constructed based on measurement instruments previously reported on and validated in the contemporary literature and adapted for the present purposes. In total, these instruments address various perspectives on pre-service teachers' PDC. The participants responded to items on a five-point scale ranging from "completely disagree" to "completely agree."

TPK (technological pedagogical knowledge) was measured with five items derived from the widely used TPACK (Technological Pedagogical Content Knowledge) instrument (Schmidt et al., 2009). Instead of utilizing the entire instrument, we used only the items from the TPK variable in this study to reduce the length of the survey and to prevent survey fatigue. The psychometric properties of the TPK have been validated in several countries (Herring et al., 2016). A sample item was, "I can choose technologies that enhance students' learning in a lesson." The Cronbach's alpha values were .73 (c1) and .84 (c2).

CU-ICT (confidence in the use of ICT) was measured with three items adapted from the work of Nikolopoulou and Gialamas (2015) regarding participants' confidence for technology use in the classroom. A sample item was, "I can give students clear learning goals for their use of ICT in school subjects." Cronbach's alpha values were .76 (c1) and .84 (c2).

ICT self-efficacy was measured with four items adapted from Wang et al.'s study (2004) regarding participants' self-efficacy beliefs for successfully integrating technology into teaching practices. A sample item was, "I believe that I can master ICT in my teaching practice." Cronbach's alpha values were .87 (c1) and .91 (c2).

PU-ICT (perceived usefulness of ICT in teaching and learning) was measured with four items adapted from Scherer et al.'s study (2015). Perceived usefulness is part of teachers' belief systems and refers to their individual beliefs that using ICT will improve their job performance. A sample item was, "ICT can improve the quality of students' learning." Cronbach's alpha values were .87 (c1) and .84 (c2).

ICT and inclusion were measured with three items adapted from the Differentiated Instruction Scale (Roy et al., 2013) regarding the PSTs' ability to use ICT to address diverse learning needs among students. A sample item was, "Digital tools help me to differentiate my teaching to individual student needs." Cronbach's alpha values were .67 (c1) and .79 (c2).

Digital judgment was measured with one item adapted from the work of Røkenes and Krumsvik (2016): "How well do you master guiding pupils in developing digital judgment associated with ethical challenges that their digital lifestyle offers?"

TE-PDC (teacher educators' professional digital competence) was measured with one item adapted from the work of Røkenes and Krumsvik (2016): "To what extent do you see a need for competence development in the use of ICT for teacher educators at the university?"

Descriptive analysis

Table 1 presents descriptive statistics among all measures included in the final data analysis.

The highest correlations were found between ICT-C and ICT self-efficacy ($r = .63$, $p < .001$), TPK and ICT-C ($r = .57$, $p < .001$), PU-ICT and ICT-inclusion ($r = .51$, $p < .001$), TPK and ICT self-efficacy ($r = .49$, $p < .001$), and TPK and PU-ICT ($r = .49$, $p < .001$).

Table 1 Pearson correlations and descriptive statistics among variables in cohort 1 (above the diagonal) and cohort 2 (below the diagonal).

Variables	1	2	3	4	5	6	7	8
1.TPK		.20*	.18	.20**	.23**	-.01	-.15	.20
2. CU-ICT	.57**		.52**	.13	.24**	.49**	.-.30**	.19*
3. ICT self-efficacy	.49**	.63**		.32**	.19*	.24**	-.13*	.23*
4. PU-ICT	.49**	.33**	.41**		.51**	.04	.05	-.02
5. ICT and inclusion	.38**	.44**	.37**	.40**		-.001	-.03	.00
6. Digital judgment	.20*	.48**	.40**	.03	.14		-.05	.22*
7. TE-PDC	.08	-.07	.03	.30**	.14	-.07		-.16
8. Gender	-.07	.09	.17	-.01	-.13	.28**	-.23*	
Scale range	1 to 5	1 to 5	1 to 5	1 to 5	1 to 5	1 to 5	1 to 5	

Notes: *p < .05; **p < .001. TPK (technological pedagogical knowledge), CU-ICT (confidence in the use of ICT), PU-ICT (perceived usefulness of ICT in teaching and learning), TE-PDC (teacher educators' professional digital competence).

A principal component analysis (PCA) was conducted to check for the underlying dimensionality of the study's constructs. An inspection of the factor loading matrix showed that all variables except PU-ICT (perceived usefulness of ICT in teaching and learning) loaded to one component, with acceptable factor loadings. PU-ICT revealed three components with an unclear theoretical structure. Visual inspection of the screen plot indicated that one component, including four items with acceptable factor loadings, should be retained. The items reflected the theoretical concept of the perceived usefulness of ICT in teaching and learning. In addition, considering that the underlying structures of ICT self-efficacy and CU-ICT might be theoretically related, a PCA using varimax rotation was conducted on all seven items comprising these instruments. Tabachnick et al. (2007) recommend that only variables with loadings of .30 and above should be interpreted. The analysis identified two different and distinct underlying dimensions above an eigenvalue of 1.0, corresponding to the two variables of ICT self-efficacy and CU-ICT. The results of the PCA thus clearly showed that these two variables represent psychometrically distinct dimensions.

Results

We performed a series of separate t-tests on all variables and have reported the mean (M) differences of all variables across the two groups. The t-test analyses, means, and SDs for all measures are provided in Table 2. The results of the t-tests provide support for hypothesis (1) and clearly show a difference between the variables TPK ($t = -3.22$, $p < .001$), confidence in the use of ICT in the classroom ($t = -4.93$, $p < .001$), ICT and inclusion ($t = -2.83$, $p < .05$), and digital judgment ($t = -3.57$, $p < .001$). Interestingly, the PSTs reported a higher ICT self-efficacy in cohort 2, but the results were not significant. We should note, however, that the differences in mean values of ICT self-efficacy were similar to other variables that were significant. The lack of statistical significance could be attributed to the level of reported SD in this variable (see Table 2 for details).

The pattern of differences is in agreement with our initial assumptions concerning hypothesis 2; the mean values in cohort 2 are consistently higher than in cohort 1. Regarding hypothesis 3, the PSTs' assessment of the need for competence development in PDC for the teacher educators was lower in cohort 2 ($t = -3.58$, $p < .001$). This finding indicates that competence development has occurred among the faculty staff, which could impact their teaching and program development. The PSTs' perceived usefulness of ICT in teaching and learning did not differ significantly between the two cohorts ($M = 4.92$ in cohort 1 and $M =$

4.82 in cohort 2), which indicates that both groups perceived ICT integration as an important aspect of teaching duties. Medium to moderately large effect sizes of at least .36 (Cohen, 2013) were reported. The largest effect size ($d = .64$) was obtained for PSTs perceived confidence in using ICT in the classroom. Overall, the results indicate that the development initiatives in the five-year teacher education is associated with PSTs increased PDC.

Table 2 Descriptive statistics and results of independent sample t-tests for subscales on cohort 1 and cohort 2

	Cohort 1 (N = 128)		Cohort 2 (N = 118)			
Scale	M	SD	M	SD	*t*	*d*
TPK	3.65	.65	3.93	.72	-3.22**	.41
CU-ICT	3.03	.73	3.52	.80	-4.93**	.64
ICT self-efficacy	4.12	1.4	4.43	1.58	-1.58	.28
PU-ICT	4.92	1.38	4.82	1.39	.52	.07
ICT and inclusion	3.87	1.12	4.32	1.34	-2.83*	.36
Digital judgment	3.45	.82	3.79	.67	-3.57**	.45
TE-PDC	4.49	.64	4.14	.87	3.58**	.46

Notes: *p < .05; **p < .001. TPK (technological pedagogical knowledge), CU-ICT (confidence in the use of ICT), PU-ICT (perceived usefulness of ICT in teaching and learning), TE-PDC (teacher educators' professional digital competence).

The descriptive analysis (Table 1) also showed a significant correlation between self-efficacy and gender (cohort 1). Although not part of our initial hypothesis, we were prompted to run a t-test on self-efficacy with gender as a grouping variable. The results showed gender differences in ICT self-efficacy, with female PSTs reporting significantly lower (M = 4.09) ICT self-efficacy than male PSTs (M = 4.79) (-3.08, p < .05). This finding indicates a significant gender difference in ICT self-efficacy beliefs.

Discussion

The purpose of this study was to examine how two cohorts of PSTs perceive their PDC in the context of a teacher education reform and redesign efforts initiated by the ProDiG project. The overall findings support the study's hypothesis (1), which posits a difference between cohort 1 and cohort 2 in pre-service teachers' PDC for technology integration in the classroom. Hypothesis (2), which posits that PSTs in cohort 2 have a higher PDC for technology integration in the classroom than participants in cohort 1, was also supported. The full program redesign showed across cohort growth in pre-service teachers' TPK, confidence in the use of ICT for teaching and learning, ICT for inclusion in the classroom, and digital judgment. A significant gender difference was found in ICT self-efficacy beliefs. This finding agrees with findings from studies that have undertaken a gender perspective on ICT self-efficacy, where women seem to underestimate their abilities, and men tend to overestimate their abilities (e.g., Tømte & Hatlevik, 2011). In terms of actual ICT-related achievements, studies' results are less consistent (Hatlevik et al., 2018). The PSTs' perceived usefulness of ICT in teaching and learning was high in both cohorts and did not differ significantly. One possible explanation for this finding is that PSTs consider ICT to have a central place in the teaching profession, regardless of the teacher education program's emphasis. The perceived usefulness of ICT has been shown to have a direct and positive effect on teachers' intentions to use ICT (Teo, 2019) and to actually integrate such technologies in the classroom (Sang et al., 2010). Our results can also be seen in the context of studies that have shown that PSTs'

technology integration behaviors are affected by their beliefs in ICT's value and their efficacy with ICT (Ertmer & Ottenbreit, 2010; Joo et al., 2018). The training provided by ITE programs plays a central role in developing beliefs related to value and efficacy in teaching with technology, which in turn indirectly affects the actual use of technology in the classroom (Chen, 2010).

Overall, the present study's findings indicate that teacher education institutions are central to enhancing PDC beliefs among PSTs. Researchers highlight the need to take a multi-faceted approach to technology integration, where planning and leadership, cooperation within and between institutions, professional staff development, ensuring access to appropriate resources, and systematic change efforts, is essential (Tondeur et al., 2012; Nelson et al., 2019). Several studies have previously emphasized the need for a strong connection between campus-based teaching and field practices and the technology-rich learning activities in these environments (e.g., Polly et al., 2010). In these collaborative partnerships, expertise is shared between school-based mentor teachers and faculty staff (Lillejord & Børte, 2016). Ertmer (2003) found that collaboration between university faculty staff and mentor teachers to plan and implement technology-integrated lessons created a natural framework for modeling and leveraging their expertise. This type of modeling has been shown to be a significant predictor of those PDC aspects important to pre-service teachers (Baran et al., 2019). As mentioned above, a key development initiative at UiA has been a partnership where 14 mentor teachers from partner schools are contracted as joint faculty members (20%) to co-instruct university courses in ITE. This partnership across institutional and professional boundaries is often referred to as "boundary crossing" (Akkerman & Bakker, 2011). Partnerships provide opportunities for the relationship between theory and practice to be enhanced when knowledge of and examples from current practice are integrated more coherently (Lillejord & Børte, 2016). One of these partnerships is a new 30 ECTS course for PSTs that addresses the educational system's digital transformation as well as the teachers' role. The course links theory to practical tasks related to the seven knowledge domains that constitute the framework for PDC for teachers (Kelentrić et al., 2017). The course emphasizes explicit modeling and explanation of pedagogical reasoning, followed by PSTs collaborating on developing technology-integrated lessons guided by the teacher educators, a pedagogical approach that Mishra and Koehler (2006) called "learning technology by design" (p. 1020).

The present results, which show significant differences between the two cohorts in our study, could also be related to PDC workshops initiated in ProDiG and located in partner schools for PSTs, in-service teachers, and the university faculty. Previous researchers have emphasized that technology courses should not be isolated from the curriculum, and contents and should be situated in the school-based learning environment (e.g., Choy et al., 2008). Involving the partner schools' entire staff in planning and implementing these workshops offered them an opportunity to learn and collaborate on technology's educational use. The goal of these workshops was to involve PSTs, the university faculty, and mentor teachers in collective participation in hands-on technology practice through active learning using classroom examples from in-service teachers. This approach is in line with the work of researchers who have emphasized the importance of the content-specific practice of developing PDC (e.g., Hughes, 2005).

Finally, our results have also shown that the cohort 2 participants demonstrated a lower assessment of the need for competence development in PDC for their university lecturers. We may reasonably assume that teacher educators are role models who influence how PSTs develop their attitudes toward technology and how they perceive their efficiency in applying

technology in the classroom (Baran et al., 2019). Thus, a university faculty needs institutional support with opportunities for professional development (Nelson et al., 2019). Based on this reasoning, we therefore consider teacher educator PDC training with funded staff release time as a critical development initiative in the ProDiG project.

Limitations and recommendations for future research

Several limitations should be acknowledged. First, we do not wish to imply that the variables included in this study represent an extensive or final definition of pre-service teachers' PDC. Other relevant variables associated with PSTs' professional digital competence could be included, such as general teacher self-efficacy, ICT experience, and subject domain (Hernández et al., 2014).

Second, we also limited the use of TPACK by only measuring TPK. Including all measures of the TPACK constructs could have indicated other competencies that PSTs possessed across different subjects. In addition, the use of one item to measure digital judgment and TE-PDC involves less precision than using a multi-item instrument. The use of a multi-item scale could have improved the reliability of the instrument.

Third, although all the instruments employed in the present study showed satisfactory internal reliability, the general approach of using self-report measures to assess a complex concept such as PDC might be challenging. Although assessing pre-service teachers' PDC through self-reporting is not uncommon in the contemporary literature; previous studies have shown that PSTs inaccurately self-assess their PDC when compared to more objective assessments (e.g., Maderick et al., 2016). Self-assessment should therefore be used in conjunction with more objective means to measure pre-service teachers' PDC. Longitudinal studies would also help track competence development over time in ITE and during the first three years as in-service teachers to see if technology integration continues (Sang et al., 2010). Observational data of PSTs' technology integration in their ITE practicum, assessing the quality of teaching with technology integration, should also be included in future studies.

A fourth limitation is that we collected cross-sectional data across three years to examine the pre-service teachers' PDC before and after a major teacher education reform. Although we found significant across-cohort differences, we cannot claim to have found within-group growth. Furthermore, because this is not an experimental study, we cannot claim causality. Thus, this method does not provide evidence that the development initiatives through the ProDiG project determined the across-cohort differences. Future studies should include more experimental designs to verify the causal inferences, thus adding more validity to the conclusions.

Concluding remarks

Teacher education institutions are crucial for enhancing professional digital competence among pre-service teachers and teacher educators. The findings in this study indicate that partnerships between university and schools, involving all stakeholders, is associated with pre-service teachers' beliefs about their PDC. Pre-service teachers need opportunities to actively engage in their learning process to apply PDC in their classroom teaching. Based on our results, the outlook is promising for development initiatives that aim to improve pre-service teachers' PDC, including modeling technology-integrated teaching.

References

Abbitt, J. T. (2011). An investigation of the relationship between self-efficacy beliefs about technology integration and technological pedagogical content knowledge (TPACK) among preservice teachers. *Journal of Digital Learning in Teacher Education*, *27*(4), 134–143. https://doi.org/10.1080/21532974.2011.10784670

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, *81*(2), 132–169. https://doi.org/10.3102%2F0034654311404435

Al-Awidi, H. M., & Alghazo, I. M. (2012). The effect of student teaching experience on preservice elementary teachers' self-efficacy beliefs for technology integration in the UAE. *Educational Technology Research and Development*, *60*(5), 923–941. https://doi.org/10.1007/s11423-012-9239-4

Albion, P. R. (1999). Self-efficacy beliefs as an indicator of teachers' preparedness for teaching with technology. In *Society for Information Technology & Teacher Education International Conference* (pp. 1602–1608). AACE.

Anderson, S. E., Groulx, J. G., & Maninger, R. M. (2011). Relationships among preservice teachers' technology-related abilities, beliefs, and intentions to use technology in their future classrooms. *Journal of Educational Computing Research*, *45*(3), 321–338. https://doi.org/10.2190%2FEC.45.3.d

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191. https://psycnet.apa.org/doi/10.1037/0033-295X.84.2.191

Baran, E., Canbazoglu Bilici, S., Albayrak Sari, A., & Tondeur, J. (2019). Investigating the impact of teacher education strategies on preservice teachers' TPACK. *British Journal of Educational Technology*, *50*(1), 357–370. https://doi.org/10.1111/bjet.12565

Becker, M. R. (2000). Faculty development model: Addressing the disparity between pre-service and in-service educators in technology integration. In *Society for Information Technology & Teacher Education International Conference* (pp. 1604–1608). AACE.

Chauhan, S. (2017). A meta-analysis of the impact of technology on learning effectiveness of elementary students. *Computers & Education*, *105*, 14–30. https://doi.org/10.1016/j.compedu.2016.11.005

Chen, R. J. (2010). Investigating models for preservice teachers' use of technology to support student-centered learning. *Computers & Education*, *55*(1), 32–42. https://doi.org/10.1016/j.compedu.2009.11.015

Choi, M., Cristol, D., & Gimbert, B. (2018). Teachers as digital citizens: The influence of individual backgrounds, internet use and psychological characteristics on teachers' levels of digital citizenship. *Computers & Education*, *121*, 143–161. https://doi.org/10.1016/j.compedu.2018.03.005

Choy, D., Wong, A. F., & Gao, P. (2008). Singapore's preservice teachers' perspectives in integrating information and communication technology (ICT) during practicum. *Proceedings of the Australian Association for Research in Education* (pp. 1–14). Canberra: AARE.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Delone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success. *Journal of Management Information Systems*, *19*(4), 9–30. https://doi.org/10.1080/07421222.2003.11045748

Ertmer, P. A. (1999). Addressing first-and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47–61. https://doi.org/10.1007/BF02299597

Ertmer, P. (2003). Transforming teacher education: Visions and strategies. *Educational Technology Research and Development*, *51*(1), 124–128. https://doi.org/10.1007/BF02504522

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284. https://doi.org/10.1080/15391523.2010.10782551

Gudmundsdottir, G. B., Gassó, H. H., Rubio, J. C. C., & Hatlevik, O. E. (2020). Student teachers' responsible use of ICT: Examining two samples in Spain and Norway. *Computers & Education*, 103877. https://doi.org/10.1016/j.compedu.2020.103877

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: Implications for teacher education. *European Journal of Teacher Education*, *41*(2), 214–231. https://doi.org/10.1080/02619768.2017.1416085

Hatlevik, O. E., Throndsen, I., Loi, M., & Gudmundsdottir, G. B. (2018). Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers & Education*, *118*, 107–119. https://doi.org/10.1016/j.compedu.2017.11.011

Hernández-Ramos, J. P., Martínez-Abad, F., Peñalvo, F. J. G., García, M. E. H., & Rodríguez-Conde, M. J. (2014). Teachers' attitude regarding the use of ICT. *Computers in Human Behavior*, *31*, 509–516. https://doi.org/10.1016/j.chb.2013.04.039

Herring, M. C., Koehler, M. J., & Mishra, P. (Eds.). (2016). *Handbook of technological pedagogical content knowledge (TPACK) for educators*. Routledge.

Hughes, J. (2005). The role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. *Journal of Technology and Teacher Education*, *13*(2), 277–302. https://www.learntechlib.org/primary/p/26105/

Instefjord, E., & Munthe, E. (2016). Preparing pre-service teachers to integrate technology. *European Journal of Teacher Education*, *39*(1), 77–93. https://doi.org/10.1080/02619768.2015.1100602

Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Journal of Educational Technology & Society*, *21*(3), 48–59.

Kaufman, K. (2014). Information communication technology: Challenges & some prospects from pre-service education to the classroom. *Mid-Atlantic Education Review*, *2*(1).

Kelentrić, M., Helland, K., & Arstorp, A. T. (2017). Professional digital competence framework for teachers. *Norwegian Centre for ICT in Education*, 1–74.

Lillejord, S., & Børte, K. (2016). Partnership in teacher education—A research mapping. *European Journal of Teacher Education*, *39*(5), 550–563. https://doi.org/10.1080/02619768.2016.1252911

Livingstone, S., Mascheroni, G., & Staksrud, E. (2015). *Developing a framework for researching children's online risks and opportunities in Europe*. London: EU Kids Online.

Macaulay, P. J., Betts, L. R., Stiller, J., & Kellezi, B. (2018). Perceptions and responses towards cyberbullying: A systematic review of teachers in the education system. *Aggression and Violent Behavior*, *43*, 1–12. https://doi.org/10.1016/j.avb.2018.08.004

Maderick, J. A., Zhang, S., Hartley, K., & Marchand, G. (2016). Preservice teachers and self-assessing digital competence. *Journal of Educational Computing Research*, *54*(3), 326–351. https://doi.org/10.1177%2F0735633115620432

Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L. (2013). Preservice teachers' TPACK: Using technology to support inquiry instruction. *Journal of Science Education and Technology*, *22*(6), 838–857. https://www.jstor.org/stable/24019762

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://www.learntechlib.org/p/99246/

Negishi, M., Elder, A. D., Hamil, J. B., & Mzoughi, T. (2003). *Predicting elementary education candidates' technology integration during their field placement instruction*. Paper presented at the annual meeting of the Mid-South Educational Research Association, Biloxi, MI.

Nelson, M. (2017). The role of a mentor teacher's TPACK in preservice teachers' intentions to integrate technology. *Journal of Technology and Teacher Education*, *25*(4), 449–473. https://www.learntechlib.org/primary/p/178211/

Nelson, M. J., Voithofer, R., & Cheng, S. L. (2019). Mediating factors that influence the technology integration practices of teacher educators. *Computers & Education*, *128*, 330–344. https://doi.org/10.1016/j.compedu.2018.09.023

Nikolopoulou, K., & Gialamas, V. (2015). ICT and play in preschool: Early childhood teachers' beliefs and confidence. *International Journal of Early Years Education*, *23*(4), 409–425. https://doi.org/10.1080/09669760.2015.1078727

Polly, D., Mims, C., Shepherd, C. E., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology. *Teaching and Teacher Education*, *26*(4), 863–870. https://doi.org/10.1016/j.tate.2009.10.024

Roy, A., Guay, F., & Valois, P. (2013). Teaching to address diverse learning needs: Development and validation of a differentiated instruction scale. *International Journal of Inclusive Education*, *17*(11), 1186–1204. https://doi.org/10.1080/13603116.2012.743604

Røkenes, F. M., & Krumsvik, R. J. (2016). Prepared to teach ESL with ICT? A study of digital competence in Norwegian teacher education. *Computers & Education*, *97*, 1–20. https://doi.org/10.1016/j.compedu.2016.02.014

Sadaf, A., Newby, T. J., & Ertmer, P. A. (2012). Exploring pre-service teachers' beliefs about using Web 2.0 technologies in the K–12 classroom. *Computers & Education*, *59*(3), 937–945. https://doi.org/10.1016/j.compedu.2012.04.001

Sang, G., Valcke, M., Van Braak, J., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors. *Computers & Education*, *54*(1), 103–112. https://doi.org/10.1016/j.compedu.2009.07.010

Scherer, R., Siddiq, F., & Teo, T. (2015). Becoming more specific: Measuring and modeling teachers' perceived usefulness of ICT in the context of teaching and learning. *Computers & Education*, *88*, 202–214. https://doi.org/10.1016/j.compedu.2015.05.005

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123–149. https://doi.org/10.1080/15391523.2009.10782544

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics.* (Vol. 5, pp. 481-498). Boston, MA: Pearson.

Teo, T. (2019). Students and teachers' intention to use technology: Assessing their measurement equivalence and structural invariance. *Journal of Educational Computing Research*, *57*(1), 201–225. https://doi.org/10.1177%2F0735633117749430

Tondeur, J., Aesaert, K., Prestridge, S., & Consuegra, E. (2018). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education*, *122*, 32–42. https://doi.org/10.1016/j.compedu.2018.03.002

Tondeur, J., Van Braak, J., Guoyuan, S., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. S. (2012). Preparing student teachers to integrate ICT in classroom practice: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134–144. https://doi.org/10.1016/j.compedu.2011.10.009

Tschannen-Moran, M., & Johnson, D. (2011). Exploring literacy teachers' self-efficacy beliefs: Potential sources at play. *Teaching and Teacher Education*, *27*(4), 751–761. https://doi.org/10.1016/j.tate.2010.12.005

Tømte, C., & Hatlevik, O. E. (2011). Gender-differences in self-efficacy ICT related to various ICT-user profiles in Finland and Norway: How do self-efficacy, gender and ICT-user profiles relate to findings from PISA 2006. *Computers & Education*, *57*(1), 1416–1424. https://doi.org/10.1016/j.compedu.2010.12.011

Uerz, D., Volman, M., & Kral, M. (2018). Teacher educators' competences in fostering student teachers' proficiency in teaching and learning with technology. *Teaching and Teacher Education*, *70*, 12–23. https://doi.org/10.1016/j.tate.2017.11.005

Valtonen, T., Kukkonen, J., Kontkanen, S., Sormunen, K., Dillon, P., & Sointu, E. (2015). The impact of authentic learning experiences with ICT on pre-service teachers' intentions to use ICT for teaching and learning. *Computers & Education*, *81*, 49–58. https://doi.org/10.1016/j.compedu.2014.09.008

Wang, L., Ertmer, P. A., & Newby, T. J. (2004). Increasing preservice teachers' self-efficacy beliefs for technology integration. *Journal of Research on Technology in Education*, *36*(3), 231–250. https://doi.org/10.1080/15391523.2004.10782414

Wilson, M. L., Ritzhaupt, A. D., & Cheng, L. (2020). The impact of teacher education courses for technology integration on pre-service teacher knowledge: A meta-analysis. *Computers & Education*, *156*, 103941. https://doi.org/10.1016/j.compedu.2020.103941