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Developing early career teachers' professional digital competence: a systematic literature review

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ABSTRACT

Early-career teachers face numerous challenges when using digital technologies in their educational practices. This systematic literature review explores how early-career teachers develop professional digital competence in practice and identifies some of the contributing factors for this development. Twenty-five publications were selected for inclusion in the review study after a careful search strategy and detailed screening conducted in three popular and relevant databases (Web of Science, Scopus and ERIC). The analysis of the reviewed publications revealed four overarching themes (actively developing professional digital competence, taking advantage of development opportunities, mentoring as a way of development, and professional digital competence interwoven with early-career teachers' professional identity development). The analysis also revealed five factors (institutional culture, accessibility and availability of resources, governance and leadership, insufficient or lack of technical and pedagogical support and a heavy workload) contributing to early-career teachers' professional digital competence development. The systematic review offers conclusions and research implications.

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1 Introduction

The transition from preservice teacher education programmes to the teaching profession is often characterised as a period of exploration, adaptation and learning (Clausen 2007; Tondeur et al. 2017). In this transition, Early Career Teachers (ECTs) face numerous challenges when adopting and using digital technologies in their educational activities. ECTs refer to newly qualified teachers who are at the early years of their teaching profession (Schaap et al. 2021). Such initial years of teaching could be seen as a crucial phase for their professional growth regardless of their teacher training preparation programmes. An increasing number of studies show that ECTs encounter a range of difficulties when integrating digital technologies into their new and demanding roles (Gurevich, Stein, and Gorev 2017; Hammond et al. 2009; Hanell 2018).

Educational institutions struggle to help ECTs integrate digital technologies into their educational activities (König, Jäger-Biela, and Glutsch 2020). A variety of

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strategies and approaches have been attempted to try and support and develop ECTs' professional digital competence (PDC), including reduced timetables and the provision of both formal support mechanisms and informal encouragement (Starkey 2010a; Tondeur et al. 2017). Supporting ECTs in the transition from teacher education to the classroom is critical. Enabling them to swim, rather than sink, can make a positive contribution to their job satisfaction and performance (Schuck et al. 2018). The COVID-19 pandemic has confronted ECTs, like all other teachers, with the harsh reality of everyday classroom practice in a crisis situation (van der Spoel et al. 2020). To deal with this, ECTs have had to learn to (partly or fully) integrate digital technologies and resources into their educational activities.

There is a widespread consensus that ECTs feel they have not been fully prepared to integrate digital technologies into their educational activities (Gudmundsdottir and Hatlevik 2018; Masoumi 2021; Orlando and Attard 2016; Tondeur et al. 2017). Furthermore, the literature suggests that a limited number of ECTs are able to create learner-centred learning environments using digital technologies (Gao et al. 2011; Gong and Lai 2018; Starkey 2010b).

This issue is important to highlight when we consider the harsh reality that ECTs are often faced with in schools and the existing contextual and cultural pedagogical conditions that prevail there. The real-life context an ECT finds themselves in will shape more than anything else whether and how they are able to integrate digital technologies into their educational activities. ECTs who are regarded as digital natives – those with a high level of technological knowledge and are more open to using digital technologies – are often expected to bring about change and act as change agents (Bate 2010; Gao et al. 2011; Ottenbreit-Leftwich et al. 2018).

Previous studies have explored how teachers develop their PDC, the extent to which they adapt digital technologies in their practices, their school context and other characteristics that enable or hinder the integration of digital technologies into their educational activities (Ottenbreit-Leftwich et al. 2018; Starkey 2020; Tondeur et al. 2017). These studies have highlighted in particular a number of factors that contribute to teachers' PDC, including an institution's culture, availability and technical support, teachers' own digital literacy and their resistance to change, and the extent to which the support gatekeepers can offer is influenced by their workload. In addition, an increasing number of studies have begun to investigate how teacher education institutions prepare and develop pre-service teacher's digital competences (Brevik et al. 2019; Masoumi 2021). ECTs PDC, however, has rarely been studied. Further, there is no review study exploring how ECTs develop their PDC in practice and what are the possible contributing factors for this development.

This study thus explores how ECTs develop their PDC in practice and identifies some of the contributing factors for this development. Investigating ECTs PDC provides collective evidence to explore how the ECTs PDC can best be developed, and which factors contribute to their transition as digitally competent teachers. This can contribute to the problem of ECTs attrition and retention in the profession as well as students' learning (Gudmundsdottir and Hatlevik 2018). In addition, identifying challenges and success factors that inform ECTs about their PDC can help us understand how best to support

and empower them in the early years of their careers in an age of disruptive technology changing learning and teaching process.

2 Professional digital competence

Digital competence, as one of the eight key competences for lifelong learning (European Commission 2006), is a complex concept that encompasses a broad set of knowledge, attitudes and skills. In the European Digital Competence Framework for Citizens, digital competence is split into five specific areas: 1) information and data literacy; 2) communication and collaboration; 3) digital content and creation; 4) safety and well-being; and 5) problem solving. These areas address both technical and practical/attitudinal dimensions.

Digital competence in education has been addressed using different terms and concepts, such as digital literacy, information and communication technology literacy and digital skills. More recently, it has been referred to as professional digital competence, as a collection of the competencies and skills required to understand and use digital technologies in educational practices. There are several theoretical stances and conceptual frameworks explaining the use of digital technologies in educational activities as well as describing the characteristics of teachers' digital competence. UNESCO's Information and Communication Technology Competency Framework for Teachers (UNESCO 2018) underlines the importance of technological training to develop teacher PDC and thus to optimise their professional performance in the classroom. Addressing the challenges teachers face in combining content, educational and technological knowledge, Mishra and Koehler (2006) developed the Technological Pedagogical Content Knowledge (TPACK) model which is the most widely-accepted framework in the literature demonstrating how technological, pedagogical and content knowledge can be effectively integrated to support students' learning (McGarr and McDonagh 2019). The Substitution Augmentation Modification Redefinition (SAMR) framework suggests how digital technology can impact and transform teaching and learning environments (Puentedura 2014).

Using the TPACK framework, Brevik et al. (2019) provide a conceptual model for PDC that is based on four pillars, including generic digital competence, subject/didactic digital competence, profession-oriented competence and transformative digital agency. In this conceptual model, teachers' integration of digital technologies transcends their subject specific pedagogy and addresses in addition 'school-home communication, the psychosocial learning environment, classroom management and relational skills, and teachers' own research and continuous professional development in the field of ICT' (Gudmundsdottir and Hatlevik 2018, 4). McGarr and McDonagh (2019), further, propose an intuitive model that includes teachers' technical skills, pedagogical skills, cyber-ethics and attitudes and openness to new technologies. In addition, several important frameworks have been developed to measure and develop required digital competence (cf. (International Society for Technology in Education's (*ISTE) Standards for Educators* 2017). While important when seeking to understand the integration of digital technologies into education, these frameworks are not entirely relevant for the purposes of our study.

Digital competence in education is much more than a skilful, creative and safe use of digital technologies. It is a complex competence informed by individual teachers' perceptions of learning and teaching, their subject context and its internal didactic practices, as

well as any local and national traditions and policies for administering and safeguarding students and teachers. In addition to a skilful and critical use of digital technologies, digital competence in education also aims to develop students' digital competences (Lund et al. 2014). By acknowledging the relevance and importance of technical knowledge and skills, digital competence in education adopts wider personal and sociocultural stances. In summary, PDC goes beyond teachers' existing technical skills. For ECTs to display PDC they need to possess sufficient technical, pedagogical and ethical skills so that they will be open to emerging digital technologies that will help them to break out of their current forms of practice and take the necessary steps towards transformation. Based on this operational definition, the following research questions have been formulated to investigate how the PDC of ECTs is developed:

(1) How is the PDC of ECTs developed in practice?
(2) What are the main factors that contribute to the development of ECTs' PDC?

3 Methodology

To understand how the PDC of ECTs is developed and which factors contribute to this development, a replicable, transparent and systematic process to review the existing research literature was carried out. This review identified a set of criteria for the inclusion and exclusion of the reviewed research. The research was then analysed, compared and synthesised in a way that was methodical, logical, and transparent (Alexander 2020).

As a first step, using Merriam-Webster's Online Thesaurus, additional synonyms associated with the concept of ECTs PDC were identified. In discussion with other members of the research team, the authors then refined this provisional list into the following keyword string: [early career OR novice OR new OR begin* OR initial AND teacher OR instructor OR trainer OR educator AND ICT OR information and communication technolog* OR information * technolog* OR digital* AND professional digital competence OR digital competence*]. The bibliographical full-text databases Scopus, Web of Science (WoS) and the Education Resources Information Center (ERIC) were identified as best suited for the study's primary search. Searches in these databases using this keyword string were carried out in March 2021 and resulted in 909 unique publications.

As part of the *first set of inclusion criteria*, the search parameters focused on peer-reviewed scientific journal articles in English dating from 2000 onwards. After the removal of duplications, this resulted in 485 unique publications.

In the next phase, the titles, abstracts and, where necessary, the full texts of these 485 articles were screened using the web-based tool Rayyan (rayyan.qcri.org) in order to discern their relevancy. Based on the *second set of inclusion and exclusion criteria*, 273 publications were excluded because they were targeted at, for this study, irrelevant populations such as teachers, pre-service teachers, subject teachers, school leaders and students. One hundred and twenty-six publications were excluded because they did not focus on PDC and 24 were removed because they were not based on empirical evidence. Further non-relevant reports, editorials, letters, and protocols were also excluded ($n = 8$).

As a result of the second set of inclusion and exclusion criteria, a total of 54 articles were included in our study. These full-text articles were then analysed for eligibility. Twenty-three publications were then removed because they did not focus on ECTs PDC

but rather on ECTs' attitudes towards digital acceptance, using technologies and other competences such as teaching skills. Nine additional studies were excluded because of their focus on the comparison of ECTs' PDC with other experienced teachers, which fell outside the frame of this study.

In order to identify studies that may have been overlooked in the primary literature search, in the final step, a snowball method was applied by tracking citations from the included studies. This process resulted in the addition of three publications which met all of the inclusion criteria for this review study. In total 25 relevant publications met the inclusion criteria and were selected for further analysis. A detailed outline of the process and publications is included in Appendixes 1 and 3.

The 25 articles included in this study were analysed and categorised through a process of open coding (Corbin and Strauss 2015). This process was based on the study's research questions whereby the codes were arrived at during the reading of the included studies. A careful reading and re-reading of the included studies led to the identification of key themes that were then given their own codes. For example, that the literature suggested that ECTs developed their PDC through being with or discussing with other experienced teachers, getting pedagogical and/or technical support, and being keen to explore and construct their own PDC were identified as individual themes and each given a separate code, such as, in this case, 'apprenticeship and peer learning', 'pedagogical support', 'technical support' and 'motivated and determined to develop their PDC'. Within these themes, the codes led to the generation of further subthemes. This process enabled us to focus on the particulars of each study without losing sight of the bigger picture.

ATLAS.ti 9.1 was used to identify relevant quotes and specific examples from the included articles. When data saturation was reached and no new codes emerged, the codes that had been identified were categorised into themes. The analysis process was carried out by the first author. In order to enhance inter-rater reliability for analysing the included publications, an experienced researcher who was not part of this research was invited to code articles using the developed coding schema. Overall, there was good agreement between the two coders' judgements. The calculated inter-rater reliability was .89 (Krippendorff's alpha) indicating acceptable consistency. We used both deductive and inductive approach to report the findings of this review study. We used deductive approach and applied coding categories to come up with the frequency of the categories. We then used inductive approach to find a certain number of publications supporting a specific statement.

Through this analysis, the ways ECTs develop their PDC and the factors that inform that process were organised into 12 categories. These categories were further developed and then summarised (see Appendix. 2). Contextual issues, such as the type of study and study context, were also included.

4 Findings

ECTs were given a variety of names in the studies reviewed here. 'Novice', 'new, beginning', 'early career', 'budding' teachers are a few examples. The number of years of teaching to be considered as ECT varies among scholars. Most studies defined ECTs as newly employed teachers who had been teaching for less than three years (Gudmundsdottir and Hatlevik 2018; König, Jäger-Biela, and Glutsch 2020; Schuck et al. 2018). However, the study conducted by Orlando and Attard (2016) defined ECTs as

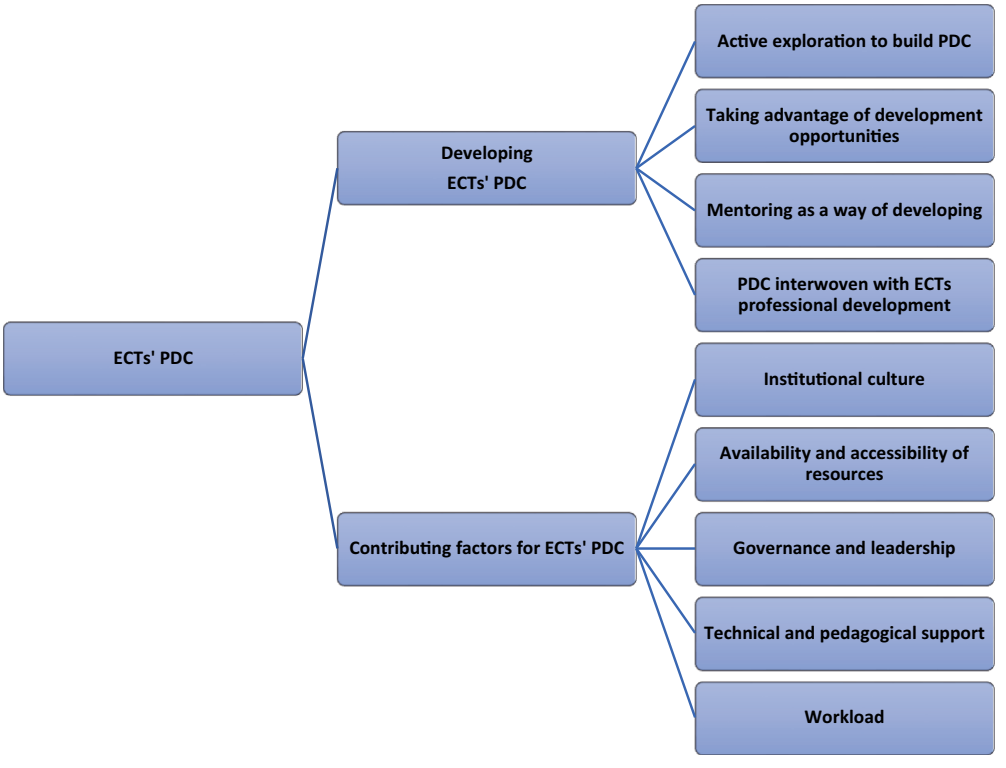

Figure 1. Themes and factors contributing to the PDC of ECTs.

a teacher who had been teaching for less than five years. A few studies did not provide a precise definition of the ECTs (Meskill et al. 2002).

PDC has been operationalised differently in the literature. In some studies, the focus was placed on ECTs' technical skills in terms of being able to use digital technologies (cf. Clausen 2007; Meskill et al. 2002; Mukama and Andersson 2008). In these studies, the PDC was mostly teacher and/or technology-centred and was aimed at enhancing the quality and quantity of teaching. In several other studies, the PDC was defined more as a skilful and safe use of digital technologies. In this approach, PDC was understood as a more complex competence and the research focused on the ways ECTs transform their educational activities using digital technologies (cf. Gudmundsdottir and Hatlevik 2018; Gurevich, Stein, and Gorev 2017; Ottenbreit-Leftwich et al. 2018). Interestingly, about 45% of the studies were guided by a TPACK framework which shows the importance of this model for ECTs PDC. Nearly half of the studies, however, (48%), did not provide any explicit theoretical perspective.

Four main themes addressing how ECTs develop their PDC were emerged. Furthermore, five contributing (enabling and constraining) factors for the development of the PDC of ECTs were identified (see Figure 1).

4.1 How is the PDC of ETCs developed?

4.1.1 Active exploration to develop PDC

Most studies revealed that ECTs take charge of their own PDC. Their PDC was a result of their individual explorations and involved the active exploration and construction of their own competences (Agyei and Voogt 2014; Dalgarno and Colgan 2007; Gao et al. 2011; König, Jäger-Biela, and Glutsch 2020). In this process of construction and development, the research shows that ECTs continuously seek opportunities to acquire direct experiences by adopting digital technologies in their educational activities.

For instance, the findings of Ottenbreit-Leftwich et al. (2018) show that ECTs develop their PDC by means of self-exploration, whereby they gain knowledge related to the integration of digital technology on their own. The commitment and desire of ECTs in terms of 'never fear the unknown, explore it!' helped them to take both initiatives and risks by using a variety of technologies to enhance student learning.

In addition, the explorations and risks ECTs took helped them to be more confident about engaging in risk-taking activities using digital technologies which led to them acting as catalysts for the greater integration of digital technologies into classroom environments and their colleagues' professional development (Gao et al. 2011; Tondeur et al. 2017). It is through this ongoing process that ECTs construct and re-construct their PDC.

Most publications have shown a positive view of the ECTs regarding the potential of digital technologies to enhance the teaching and learning process (Bate 2010; Ottenbreit-Leftwich et al. 2018; Slaouti and Barton 2007). ECTs who had a greater familiarity with using technologies were more open to the integration of digital technologies in educational activities (Alexander and Kjellstrom 2014). Such positive attitudes and outlooks informed the ways ECTs encountered digital technologies in educational settings (Hammond et al. 2009; Starkey 2010b; Wu et al. 2016). Similar findings were reflected in the study of Instefjord and Munthe (2017) who reported that there was a strong bond between teachers' self-reported efficacy and their PDC.

4.1.2 Taking advantage of development opportunities

Several studies revealed that ECTs do take advantage of the formal/informal opportunities offered to them to develop their PDC (Gong and Lai 2018; Mukama and Andersson 2008; Ozgun-Koca, Meagher, and Todd Edwards 2011). Induction programmes, technology internships and other offered in-service education activities enabled ECTs to expand their PDC. ECTs were interested in taking part in the opportunities provided to them to expand their PDC. For instance, Alexander and Kjellstrom (2014) found that ECTs who took part in a technology-based internship were more willing and better equipped to integrate digital technologies into their educational activities. They noted that during the internship, ECTs were exposed to the challenges and situations they were likely to encounter in an actual classroom, an experience which supported their PDC.

Being and interacting with other teachers, seeing their ways of planning and teaching in the context, nurturing or being part of an online/offline professional community and attending workshops or conferences were all identified as enabling ECTs to develop their PDC (Gudmundsdottir and Hatlevik 2018; Orlando and Attard

2016; Starkey 2010a). Andersson (2006) showed that the interaction between more experienced colleagues and newly qualified teachers makes boundary-breaking changes possible among ECTs. More experienced teachers often demonstrate exemplary use of technologies in content-specific area(s) which help ECTs to expand their PDC (Gudmundsdottir and Hatlevik 2018; Mukama and Andersson 2008; Orlando and Attard 2016).

In addition, several studies underlined the importance of creating or joining communities of practice, where ECTs could collaborate and share activities and resources with their colleagues (Agyei and Voogt 2014; Dalgarno and Colgan 2007; Meskill et al. 2002). Being part of and engaging in a community of practice/s enables ECTs to share, collaborate, reflect and actively develop their PDC. ECTs also had the opportunity to reflect on their own PDC plan by watching video recordings of their own teaching. Each one of these forms of in-service professional development has been shown to help ECTs reflect on their teaching practices and expand their PDC.

Several studies revealed the importance of providing informal and contextual in-service professional development opportunities for ECTs PDC (Agyei and Voogt 2014; Orlando and Attard 2016; Wu et al. 2016). The findings in these studies show that ECTs value informal learning most because it allows them to construct their PDC as part of a socially and culturally situated process.

4.1.3 Mentoring as a way of developing

Mentoring was frequently highlighted as the most important method for supporting ECTs PDC in the reviewed studies (Clausen 2007; Hammond et al. 2009; Ottenbreit-Leftwich et al. 2018; Starkey 2010a; Tondeur et al. 2017). By motivating and exemplifying how technologies can be used to provide constructive feedback, for example, mentors can support ECTs in their PDC development, especially when they are struggling to explore the relationship between the written curriculum and the reality of classroom practice.

The studies indicate the importance of providing high-quality mentoring for developing the PDC of ECTs (Hammond et al. 2009; Ottenbreit-Leftwich et al. 2018). Tondeur et al. (2017, 171) found that 'as a result of the encouragement and opportunities provided by the mentors to experiment with different technologies during the internship, both teachers [ECTs] appear to have been motivated to start integrating technology in their practice', which raised their confidence in using technologies more effectively in their teaching. Other studies also showed that good mentorship (including emotional, pedagogical and technical support) helps ECTs to expand their PDC and use digital technologies with their students in different ways (Clausen 2007; Ottenbreit-Leftwich et al. 2018; Tondeur et al. 2017).

Some studies reported that providing administrative support and making a good match between ECTs and digitally competent mentors are important for the development of an ECTs' PDC. However, finding a good mentor can be difficult. Several studies showed that ECTs may find their mentors not digitally competent and thus unable to help them develop their PDC (Hammond et al. 2009; Orlando and Attard 2016). Other ECTs showed to be critical of the limited support and time were allocated to their mentor and were thus sceptical of the way in which such mentorship could make for expanding their PDC.

4.1.4 PDC interwoven with ECTs professional development

Developing PDC is a dynamic process that shapes the understanding, attitudes and approach to teaching and learning of the ECTs, which could influence o their decisions about teaching in a particular context (Gong and Lai 2018; Orlando and Attard 2016). This dynamic process is considered to be a key factor informing ECTs' PDC and thus determining the kind of teacher they are likely to become. In this sense, developing ECTs' PDC cannot be detached from their pedagogical and content-pedagogical competences. This issue was highlighted in most of the reviewed studies, particularly those published after 2014 (Agyei and Voogt 2014; Gong and Lai 2018; Stein, Gurevich, and Gorev 2020). This idea of an integrated development process aligns well with the Mishra and Koehler (2006)' TPACK model which suggests that the development of teachers' PDC aligns with their pedagogical, technological and content knowledge and builds on the synergies between them.

Pedagogical-content and technological-pedagogical knowledge were key predictors in enabling ECTs to develop their educational expertise (Gong and Lai 2018; Starkey 2010a; Wu et al. 2016). Orlando and Attard (2016), for instance, illustrated that content and pedagogical knowledge both inform the ways in which ECTs integrate digital technologies.

Several studies showed that a large number of ECTs were not able to use digital technologies to create student-centred learning environments (cf. Agyei and Voogt 2014; Bate 2010; Ozgun-Koca, Meagher, and Todd Edwards 2011). This may signify that the development of ECTs' PDC is inseparable from their wider professional development, a process which is in turn formed and reformed by the specific context in which the teachers' pedagogical and content knowledge is developed. When the development of an ECT's PDC aligns well with other competences, they become change agents and catalysts to create technology-rich learning environments and are able to lead the transformation of the educational process.

4.2 What are the contributing factors for the development of PDC amongst ECTs?

4.2.1 Institutional culture

Institutional culture refers to the eclectic environments, that is, the norms, values and shared assumptions, through which ECTs construct and reconstruct their thoughts, feelings and behaviours. These shared norms and values may also inform and shape the ECTs' PDC (Gong and Lai 2018; Ottenbreit-Leftwich et al. 2018). Several studies indicated that a supportive institutional culture could encourage ECTs to create technology-rich learning environments (Agyei and Voogt 2014; Clausen 2007, Tondeur et al., 2017; Hammond et al. 2009). Hammond et al. (2009), for instance, found that high expectations about the use of technologies in a school's educational culture could encourage ECTs to develop their PDC and adopt those technologies in their practices. Similarly, Tondeur et al. (2017, 165) found that an ECT 'advocates and plans specifically for the integration of ICT [information and communication technology] in her instructional activities as well as directing students to engage in ICT tasks' if 'she has a supporting and enabling school culture'.

In the same way, it was found that 'unenthusiastic school cultures' limited the use of digital technologies (Bate 2010). In a study conducted by Gao et al. (2011), the actions of nine Singaporean ECTs were documented during their first year of teaching.

The results showed that the majority of the studied ECTs 'cannot translate their constructivist orientation into practice because they are often held in check by … institutional habits and feel a sense of enculturation to fit into the school culture. Therefore, they choose to become a follower or a doer' (Gao et al. 2011, 221). The study argued that ECTs can integrate technologies into their practice in three different ways: as a *follower* 'who imitates the established practices by choosing to occasionally use ICT'; as a *doer* 'who frequently uses ICT to enhance teaching within the classroom'; and as an *emerging teacher leader* 'who changes the interaction between teacher and students in the classroom and extends his/her influence beyond the classroom' (Gao et al. 2011, 2015). The dominant discourses of teaching, how learning environments are shaped and how much autonomy teachers have may either assist or hinder ECTs to integrate digital technologies into their educational activities (Agyei and Voogt 2014; Gao et al. 2011; Starkey 2010a). Another issue which was particularly highlighted in most of the studies reviewed is the importance of ECTs' engagements in teachers' professional communities and the ways these communities inform the ECTs PDC (Ottenbreit-Leftwich et al. 2018; Tondeur et al. 2017).

ECTs have a range of basic values and norms for learning and teaching with digital technologies that shape their way of teaching. On the other hand, they are expected to work according to the school's cultural-pedagogical values. This issue is particularly addressed in the studies conducted in Asian countries where ECTs were presented as being often 'held in check by personal and institutional habits' and as feeling 'a sense of enculturation to fit into the school culture' (Gao et al. 2011, 221). Helping ECTs to realise and reflect on their own tendencies and the school's written and unwritten rules can help them to overcome both self- and socially imposed challenges (Gong and Lai 2018).

The cultural features that particularly influenced the PDC of ECTs in the reviewed studies are outlined in Figure 2.

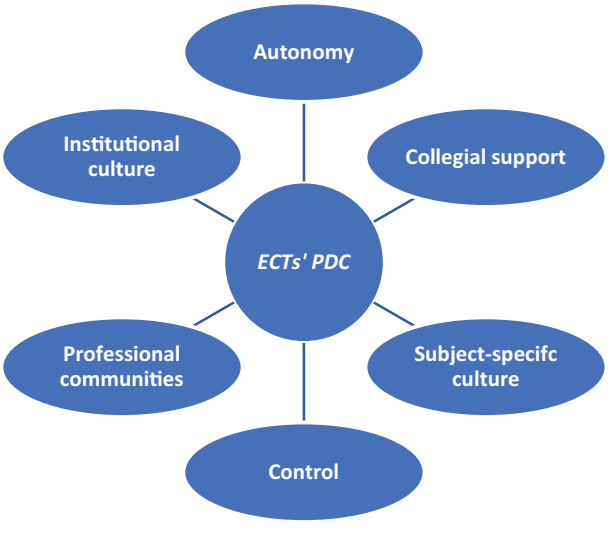

Figure 2. Cultural features that inform the PDC of ECTs.

These cultural features are socially constructed and reconstructed in educational institutions by means of teachers' actions and reactions. They overlap and intertwine with each other to a considerable extent, although they can also be seen as separate factors informing ECTs' PDC. For instance, involving ECTs in a school's decision-making processes regarding technology and giving them a sense of how this is controlled by a school's leadership can overlap with the collegial support individual teachers offer to ECTs on an informal basis.

4.2.2 Availability and accessibility of resources

Most reviewed studies indicated that the availability and accessibility of digital technologies and resources are important contributing factors for the development of PDC (Bate 2010; Dawson 2008; Gurevich, Stein, and Gorev 2017; Hammond et al. 2009; Slaouti and Barton 2007). Such access or the lack of access to digital technologies can either help or hinder an ECTs' PDC development respectively. One teacher exemplified this idea when they said '[My school] became 1:1 this year. I definitely focus on technology based on what I have available. I just think how could I use this so that my kids can get the most out of it?' (Ottenbreit-Leftwich et al. 2018, 11).

Equally, reviewed studies showed that insufficient access to technologies can prevent ECTs from adopting them in their educational activities. Agyei and Voogt (2014, 11) claimed that even the most enthusiastic ECTs, without sufficient access to digital technologies could 'do little more than rotate students through teachers' personal computers in their classrooms'. This had the potential to 'weaken newly qualified teachers' confidence and prevent them from developing higher levels of ICT self-efficacy' (Gudmundsdottir and Hatlevik 2018, 225). Limited access to technologies can thus prevent ECTs from developing their PDC and limit their ability to use technologies in their educational activities. Greater accessibility, on the other hand, not only encourages ECTs to adopt technologies in their educational activities but also enables them to meet their schools' and gatekeepers' expectations regarding the development of their PDC and adoption of technologies in their practices (Hammond et al. 2009).

In recent studies conducted in countries like Norway and Germany, the availability of digital technologies no longer seems to be a significant challenge (Gudmundsdottir and Hatlevik 2018; König, Jäger-Biela, and Glutsch 2020). However, availability is one of the key barriers in adopting digital technologies and developing ECTs' PDC in developing countries (Agyei and Voogt 2014; Wu et al. 2016).

4.2.3 Governance and leadership

Several studies reported that the governance and leadership in educational institution could play a significant role for the ECT's PDC (Mukama and Andersson 2008; Ozgun-Koca, Meagher, and Todd Edwards 2011; Starkey 2010a; Tondeur et al. 2017). This underlines the school administration' key role in developing digital technology policies, strategies and infrastructures, embedding digital technologies in the curriculum and supporting and encouraging ECTs to create technology-rich learning environments. The school administrator's approach to technologies affects the way in which ECTs develop their PDC (Clausen 2007; Mukama and Andersson 2008; Stein, Gurevich, and Gorev 2020; Tondeur et al. 2017). The studies, further, have demonstrated how school administrators support, motivate and enable ECTs to develop their PDC.

From another standpoint, some studies indicated that school administrations knew little about ECTs' PDC and what it would need to enable ECTs to effectively teach a given content (Agyei and Voogt 2014; Bate 2010; Stein, Gurevich, and Gorev 2020). This may explain why some school administrations may not have given any priority to developing the resources that help ECTs to integrate technologies into their classroom. These findings highlight the necessity of developing school leaders' own PDC.

Several other studies indicated that involving ECTs in the decision-making processes could be a contributing factor for the ECTs PDC (Agyei and Voogt 2014; Ozgun-Koca, Meagher, and Todd Edwards 2011; Wu et al. 2016). The studies indicated that the participation of ECTs in this process enhances their sense of responsibility and motivates them to actively engage in creating technology-rich learning environments. Ozgun-Koca, Meagher, and Todd Edwards (2011) exemplified how involving ECTs in obtaining technological artefacts motivated them to further develop their PDC.

4.2.4 Technical and pedagogical support

Technical and pedagogical support for ECTs was a prevalent theme for their PDC in most of the reviewed publications. It was, in fact, the lack of support that some ECTs received that proved a critical challenge when designing technology-enhanced learning activities and developing their PDC (Agyei and Voogt 2014; Bate 2010; Starkey 2010a; Stein, Gurevich, and Gorev 2020).

Several studies showed that PDC development is supported when ECTs work closely with a technical coordinator to design and conduct learning activities (Bate 2010; Dawson 2008; Starkey 2010a; Stein, Gurevich, and Gorev 2020). In a similar vein, Bate (2010) argues that we need to rethink support structures so that teachers can get 'just in time' and 'just in case' support.

The reviewed publications also underlines the importance of pedagogical support to help ECTs design technology-rich learning environments (Ottenbreit-Leftwich et al. 2018; Starkey 2010a; Tondeur et al. 2017). Some studies showed, for example, that a lack of pedagogical support was a key obstacle to ECTs developing technology-rich learning environments. Most reviewed studies revealed that ECTs use a range of technological applications to deliver content to students (Gao et al. 2011; König, Jäger-Biela, and Glutsch 2020; Stein, Gurevich, and Gorev 2020) rather than using those applications to engage students in the learning activities.

Similar findings can be found in the research carried out by Tondeur et al. (2017). Their research indicates that ECTs have a low adoption of technological, pedagogical and content knowledge and that their use of technologies are mostly teacher and/or technology-centred rather than learner-centred. Other studies point out that pedagogical support from an educator with technological, pedagogical and content knowledge in the same subject as the ECT can contribute significantly to their PDC development.

4.2.5 Workload

There is widespread consensus in the literature that the heavy workload of ECTs negatively affects ECTs' PDC (Dawson 2008; Gao et al. 2011; Mukama and Andersson 2008; Stein, Gurevich, and Gorev 2020; Wu et al. 2016). ECTs are already overloaded with a range

of duties in addition to their regular teaching, including administration, planning and assessing students' achievements. The integration of digital technologies into teaching activities can be seen to take up too much time, especially when ECTs are already struggling to come to grips with a given syllabus and meet the required learning outcomes in a short period of time.

The burden of a heavy workload can discourage ECTs from developing their PDC and designing technology-rich learning environments. Several reviewed publications suggest that devoting more time, particularly before and after enacting digital technologies in real classroom situations, could encourage ECTs to develop their PDC and transform their educational activities (Agyei and Voogt 2014; Gao et al. 2011; Mukama and Andersson 2008; Orlando and Attard 2016).

5 Discussions and conclusions

This study has focussed on the development of ECTs' PDC. Four main themes have been identified addressing how ECTs develop their PDC. These include actively exploring ways of developing PDC, taking advantage of development opportunities, having a digitally competent mentor and interweaving PDC into the ECTs' wider professional development. This review revealed that the development of ECTs' PDC takes place mostly as a result of individual teachers' explorations and experiences in classroom. ECTs learn most when they are motivated and work hard to construct a PDC that suits them. Through a process of exploration, experience and critical reflection, ECTs can develop a better understanding of how digital technology can be used in the subject being taught and in specific teaching situations. These findings further highlight that when ECTs develop their PDC they increase their potential to catalyse still further changes that could inspire, change and even affect how they adopt technologies.

The importance of active engagement of teachers in developing their own PDC is well addressed in the literature (Gao et al. 2011; Starkey 2020). These findings imply that ECTs who are not sufficiently motivated to engage with technology may find they have little chance to develop their PDC. The studies reviewed here, for instance, show that ECTs who perceive technologies to be useful and have a high self-efficacy are more likely able to explore the ways in which technologies can be integrated into their educational activities (Gudmundsdottir and Hatlevik 2018; Instefjord and Munthe 2017; Jordan 2011). Reducing the development of an ECTs' PDC to their individual motivation and personal efforts may be simplistic, considering that their motivation and engagements depend on other factors such as institutional culture, accessibility, mentoring and administrative support. Thus, adopting a systematic approach to the development of an ECTs' PDC can help to support and motivate ECTs to develop their PDC on a continuous basis.

Our review demonstrates a number of factors that encourage or discourage the development of PDC among ECTs. These include institutional culture, the availability and accessibility of resources, governance and leadership, technical and pedagogical support and workloads. The studies we examined stressed as particularly influential the role of institutional culture, the availability and accessibility of resources and presence or otherwise of a supportive leadership. Some factors were given a particular emphasis because of their national context. For instance, studies conducted in Belgium, New Zealand, and Norway stressed mentoring and peer learning while those conducted in

China and Singapore emphasised governance and leadership. These variations may be informed by cultural attributes, such as high power-distance and collectivism (Masoumi 2010). This suggests that ECTs PDC development as a culture-dependent notion need to be deeply situated in a specific context.

One recommendation which can be drawn from the reviewed studies is that formal, structured lectures and courses that took place out of context and lacked an interactive and generative component probably would not bring about significant change to the teaching practices of ECTs. Instead, creating supportive environments and informal learning opportunities not only helps ECTs to reflect on their practices and expand their PDC but also provides insights so that schools can better shape the professional development of their ECTs.

Our review showed that the different terms and concepts associated with PDC may not have a similar meaning in the published literature. In some studies, PDC is linked to the development of ECTs' technological 'know-how', as part of the expectation that ECTs need to know how to use a range of digital technologies in their teaching practices. In more recent studies, however, PDC goes beyond this narrow definition. PDC in recent studies is more commonly understood as pointing towards enabling ECTs to develop technology-rich learning environments (Gudmundsdottir and Hatlevik 2018; Gurevich, Stein, and Gorev 2017; Ottenbreit-Leftwich et al. 2018). This turn may signify that a new generation of ECTs is already able to use technologies in their everyday lives and that the question confronting them now is not mastering the tools but using them to transform teaching and learning process.

Looking forward, it seems that PDC is gradually moving beyond the display of basic technical skills, where ECTs are expected to have adequate technical, pedagogical and ethical skills, and becoming more about an attitude of openness to emerging digital technologies in order to break out of current forms of practice and take steps towards transformation. Obviously, adopting such an approach to PDC would not only define what a professional digitally competent teacher might look like, and how PDC can be systematically embedded and sustained in schools, but also how teacher education could/should prepare future teachers' professional digital competence. By providing an understanding about ECTs' PDC over time, this study contributes to ongoing discussions about how ECTs' PDC can be developed. Its findings are also important for designing desirable environments for developing ECTs' PDC in practice.

5.1 Limitations and recommendations for further research

The small number of publications that met the inclusion criteria of this study is one of its main methodological limitations. Having a broader target group of the PDC of pre-service and in-service teachers instead of only ECTs could have significantly increased the number of included studies.

That said, this systematic review shows that only a few studies have specifically focused on the PDC of ECTs. Even though these studies have made an important contribution to our understanding of teachers' PDC, more studies are needed to acquire a better and more overarching picture of the practice. In the studies examined here, the role of educational institutions and schools are poorly addressed. Some of the empirical studies do suggest how educational institutions and schools could offer in-depth opportunities for the development of PDC among ECTs. What is surprising, though, is that almost none of them examine the PDC of

ECTs in a pre-school setting. This area requires further empirical research, since teachers' PDC in early education differs from that in other educational contexts (Masoumi 2021). Furthermore, no studies have yet been conducted on school leaders' approaches to the PDC of ECTs. The role of leaders in schools and their relationship with the PDC of ECTs needs further empirical research.

None of the reviewed publications offer findings about how PDC can be related to students' learning outcomes. Further research in this area is needed to understand the relationship between developing the PDC of ECTs and student learning. In this study, the author has not explored how each of the four themes and five contributing factors for the development of the PDC of ECTs are interlinked and how they influence each other. A promising line of research for future studies would therefore be to explore such relationships in an empirical context and to develop a suitable framework thereafter.

Finally, many of the reviewed studies (45%) were guided by the TPACK framework. However, nearly half (48%), failed to provide any explicit theoretical framework or perspective for their research. It would be useful to investigate this gap further and examine any consequences it may have on the defining and developing of teachers' PDC.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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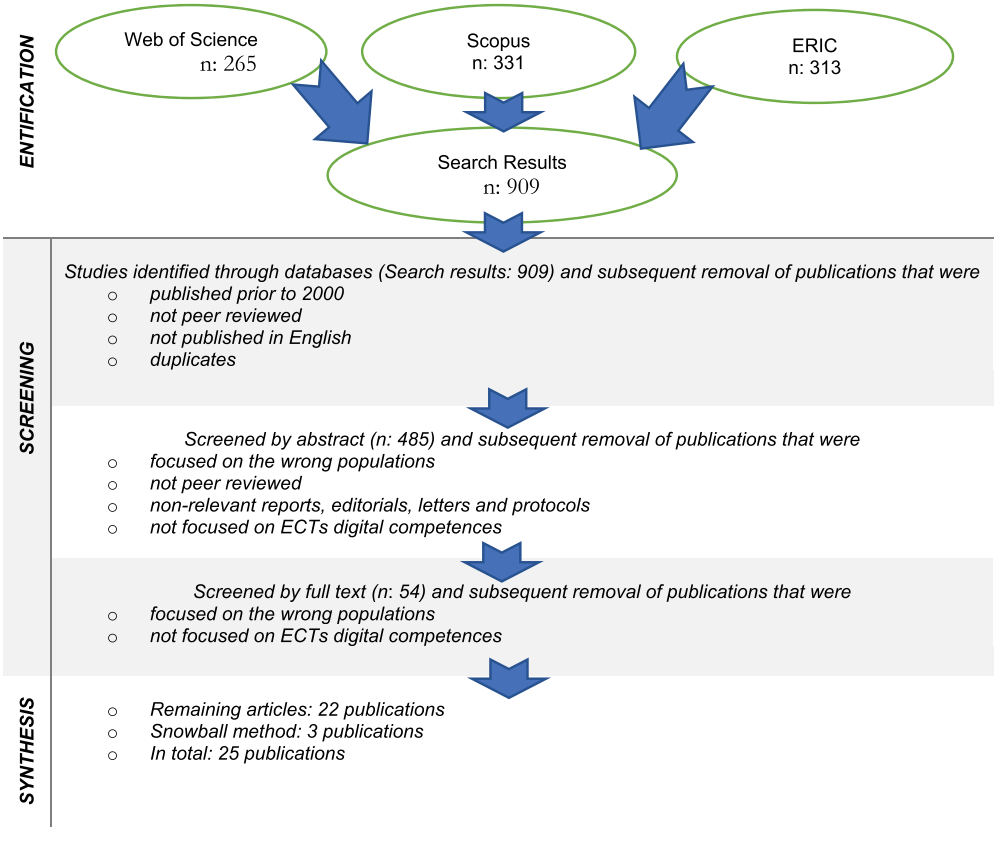
Appendices

Appendix 1: An overview of the screening and selection



Appendix 2: *Coding scheme to analyse included studies*

Category	Code	Label	Definition
Type of the study	Type of data	A1	Refers to the study which is conducted through Mixed method
		A2	Refers to the study which is conducted through Interview
		A3	Refers to the study which is conducted through Survey
		A4	Refers to the study which is conducted through other methods
The context and targeted Group	Primary school	B1	Refers to the ECTs who have been studied in the primary school
	Upper secondary school	B2	Refers to the ECTs who have been studied in the secondary school
	Higher education	B3	Refers to the ECTs who have been studied in the higher education
Theoretical stance	PDC	C1	Refers to the ways PDC is defined in the studies reviewed
	TPACK	C2	Addresses the studies that informed by TPACK
	The Other	C3	Addresses studies that informed by other theoretical frameworks such as ICT self-efficacy.
	No specific theoretical framework	C4	Addresses studies that have no specific theoretical framework
Developing ECTs' PDC	Active exploration to build PDC	D1	Refers the ways that ECTs actively explore and construct their PDC
	Taking advantage of development opportunities	D2	Refers to taking advantage of the formal/informal opportunities offered to ECTs to develop their PDC
	Mentoring	D3	Refers to ways mentors support ECTs' PDC
	Developing PDC as part of their professional development	D4	Refers to ECTs PDC development align with their other competences and as part of their professional development
	Other	D5	Refers to any other ways that ECTs PDC is developed.
Contributing factors	Institutional culture	E1	Refers to the factors that addresses the eclectic environments, i.e. the norms, values and shared assumptions through which ECTs construct and reconstruct their thoughts, feelings and behaviour
	Availability and accessibility	E2	Refers to factors that addresses the significance of availability and accessibility of digital technologies in ECTs PDC
	Governance and leadership	E3	Refers to factors that addresses the significance of Governance and leadership in ECTs PDC
	Technical and pedagogical support	E4	Refers to factors that addresses the significance of technical and pedagogical support in ECTs PDC
	Workload	E5	Refers to factors that addresses the significance of Workload in ECTs PDC
	Other	E6	Refers to any other factors that inform the ECTs PDC
	Identified gaps	E7	Refers to identified gaps in ECTs PDC

Appendix 3: A complete list of the reviewed articles

Author(s) and year	Country of study	Study's focus	Method	Type of analysis	Sample size	Context (Education level)	Theoretical framework
König, Jäger-Biela, and Glutsch (2020)	Germany	Assess teachers' opportunities to develop DC	Survey	Quantitative	89 (61 F & 28 M)	School	TPACK-model
Stein, Gurevich, and Gorev (2020)	Israel	ECTs attitudes towards the use of DT in their teaching	Qualitative (Written interview)	Qualitative	14	Secondary school	TPACK-model
Calzone, et al. (2018)	Italy	How ECTs approach DT and use DT in the classroom	Survey	Quantitative	1342 (966 F & 376 M)	Primary & secondary schools	N/A
Gong and Lai (2018)	China (Hong Kong)	ECTs technology integration practices in the classroom	Longitudinal (Interviews)	Qualitative	5 (5 F)	Primary & secondary schools	N/A
Gudmundsdottir and Hatlevik (2018)	Norway	How ECTs are prepared to use DT in their practices	Survey	Quantitative	356	Primary & secondary schools	TPACK-model & ICT self-efficacy
Ottenbreit-Leftwich et al. (2018)	Belgium	ECTs technology use & identifying the factors that support or hinder technology integration	Longitudinal (Interviews)	Qualitative (inductive thematic analysis)	6	School	N/A
Gurevich, Stein, and Gorev (2017)	Israel	Changes in choices of technological tools and attitudes towards technology use among	Qualitative (Written interview)	Mixed (statistical analysis & phenomenographic)	20 (15 f & 5 m)	Secondary school	N/a
Tondeur et al. (2017)	Belgium	How ECTs integrate technology in their practice and their pre-service learning experiences	Longitudinal (Interviews)	Qualitative (inductive thematic analysis)	16	School	TPACK-model
Orlando and Attard (2016)	Australia	ECTs experiences with mobile technologies	Mixed methods (three studies)	Qualitative (content analysis)	29	Primary school	TPACK-model
Wu et al. (2016)	China	ECTs DT professional development	Mixed method (Online surveys & interview)	Mixed (statistical analysis & thematic analysis)	144 (76 F & 68 M)	Higher education	Kirkpatrick's evaluation model

(*Continued*)

(Continued).

Author(s) and year	Country of study	Study's focus	Method	Type of analysis	Sample size	Context (Education level)	Theoretical framework
Agyei and Voogt (2014)	Ghana	ECTs transfer of learning utilising DT	Mixed method (Questionnaire; observation & interview)	Mixed (statistics, hierarchical cluster, and regression analysis)	100 (66 M, 34 F)	High school	Learning Technology by Collaborative Design
Gao et al. (2011)	Singapore	Deepen ECTs understanding performances of DT	Mixed methods (Interviews & group discussions)	Qualitative (Content analysis using NVIVO)	9 (4 F & 5 M)	Primary school	N/A
Jordan (2011)	Australia	TPACK knowledge of ECTs	Survey	Quantitative (Descriptive statistics)	64 (52 F & 12 M)	School	TPACK-model
Ozgun-Koca, Meagher, and Todd Edwards (2011)	USA	ECTs decision-making processes and TPACK development	Case study (Journal writing, observations, document analysis, & interviews)	Mixed(thematic analysis, Data triangulation)(thematic analysis, Data triangulation) (thematic analysis, Data triangulation)	1	School	TPACK-model
Bate (2010)	Australia	Discern changes in participants' pedagogical practices and their use of DT	Mixed method (Questionnaire, interview, observation)	Mixed	35	School	N/A
Hughes & Robertson (2010)	Canada	Creation & building of ECTs digital literacy	Case study (Field notes; interviews; teachers' writing; created digital artefacts)	Mixed	3	High school	Multiple literacies **
Starkey (2010a)	New Zealand	Examine barriers and enablers that influenced the integration of DT into teaching practice	Case study (Open-ended interviews and observation)	Qualitative	6	School	N/A
Starkey (2010b)	New Zealand	ECTs decisions & reasoning about using DT in their teaching practice	Case study (Open-ended interviews and observation)	Qualitative	6	School	Shulman's (1987) model of pedagogical reasoning and action
Hammond et al. (2009)	UK	ECTs use of DT in their teaching & factors which encourage and discourage that use	Qualitative (Interview & observation)	Qualitative	30	Secondary school	N/A

(*Continued*)

(Continued).

Author(s) and year	Country of study	Study's focus	Method	Type of analysis	Sample size	Context (Education level)	Theoretical framework
Dawson (2008)	Australia	ECTs preparedness to use DT & factors inhibit or facilitate the use of ICT	Case study (Questionnaire & interview)	Mixed	33	Secondary school	N/A
Mukama and Andersson (2008)	Rwandan	Creation and developing of PDC	Mixed methods (Questionnaires & focus groups)	Qualitative	18 (12F & 6 M)	Secondary schools	N/A
Clausen (2007)	USA	How ECTs development and context affects their use of technology	Case study (Interviews, observations, field notes, documents)	Qualitative	2	School	N/A
Slaouti and Barton (2007)	UK	Opportunities to develop ECTs abilities to use DT	Case-study (Questionnaires & interviews)	Qualitative (Cross-case analysis)	22	Secondary school	N/A
Andersson (2006)	Sweden	ECTs use of DT in classroom and their reasoning about use of DT	Qualitative (Interview & observation)	Qualitative	21 (17 F & 4 M)	Secondary school	N/A
Meskill *et al.* (2002)	USA	The ECTs patterns and concepts using DT	Qualitative (Interview & observation)	Qualitative	8	School	N/A

N = Number of students; N/A= Not Available; PDC= professional digital competence; DT= digital technologies; *M*= Male; F= Female.