From Tools to Complexity?

- A systematic literature analysis of digital competence among pre-service teachers in Norway

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Abstract. In the last decades, the field of education has rapidly developed along with the development of digital technology. The recent COVID-19 pandemic has affected this development, leading to an educational revolution that involves the extensive use of online learning. This change makes it crucial to understand how teachers' digital competence has developed along with this phenomenon, as well as how teacher students are being prepared to work as future teachers. This article presents a literature review regarding how the term 'digital competence' has been understood and operationalised in the context of Norwegian teacher education in the last two decades, as well as how pre-service teachers' digital competence has been measured when researched. In the earliest findings uncovered by the review, the research is tool oriented, while a greater awareness of the professional complexity of digital competence in education emerges from 2014 to 2017. From then on, a challenge arises regarding added complexity. A somewhat complex understanding of teachers' professional digital competence (PDC) makes measuring PDC a difficult task, and it is challenging to link theoretical foundations with conducted research on the subject. This article addresses these issues and contributes to the discussion regarding the term 'professional digital competence' and how it is understood in a Norwegian educational context.

Keywords: Pre-service teachers; Student teacher; Digital literacy; Professional digital competence; Early childhood.

1   Introduction

The term 'digital competence' is a moving target that has evolved along with the ongoing development of digital technology, including the way in which this technology is integrated into and changes society. Technology affects every aspect of our everyday lives and has changed the way we learn, communicate, entertain ourselves, locate information, and acquire knowledge. In 2010, *The Norwegian Centre for ICT in Edu-*

cation was established to ensure that information and communication technology (ICT) is used to improve the quality of education, learning outcomes, and learning strategies for young children, pupils, and students in higher education. In 2012, the Centre introduced the concept of 'professional digital competence', and in 2017, they published *Professional Digital Competence Framework for Teachers* (Kelentrić et al., 2017), a guidance document for policy developers, heads of department, teacher educators, teachers, and student teachers. The framework explains that these societal changes are and will continue to become increasingly apparent at every level of the Norwegian education system. This process creates new challenges for teachers' working methods in pedagogical, didactic, and administrative contexts.

In addition, the COVID-19 pandemic has affected the field of education tremendously and is referred to as part of an educational transformation. On March 12th 2020, the Norwegian government introduced the strongest and most intrusive measures ever taken during peacetime. Related to a lock-down of society, the measures included closing all kindergartens, schools, upper secondary schools, colleges, and universities. The pandemic has, for the last year and a half, helped to accelerate the use of online teaching, transforming education from physical traditional teaching to online education (Maity et al., 2021). According to Lall and Singh (2020), this shift may be one of the largest educational experiments to date, one that is changing the context of education and educational practices. Digital competence is understood as a moving target, but it may never have moved as fast as it has in the last year and a half.

Biesta (2016) writes that, in discussing digital technology and education, questions regarding the purpose of education, the content of education (curricula), and the form of education (pedagogy and didactics) are central. As Erstad et al. (2021) states, it is of fundamental importance to understand how the terms 'digital competence' and 'digital literacy' have become integrated elements in curricula, as well as how these terms relate to the changes seen in educational systems. This paper reviews how digital competence is understood and operationalised in educational policy and research in Norway, as well as how Norwegian pre-service teachers' digital competence has been measured. The review contains peer-reviewed research papers published between 2000 and 2021.

Regarding the content of education, various white papers and formal strategies have addressed digital technology in Norway since the 1990s (Hatlevik et al., 2013; NOU, 2014). Despite a series of previous strategies, the program for digital competence 2004–2008 (Ministry of Education and Research, 2004) was the first strategy treating digital technology as an integrated element of education. This was further established through the educational reform *The Knowledge Promotion* (Ministry of Education and Research, 2006b), in which digital competence was defined as one of five basic skills implemented in all subjects for all grades in primary and secondary education. With this reform, Norway was among the first countries in the world in which digital competence was included as a core element of a national curriculum (Erstad et al., 2021). Since this reform, the understanding of the term 'digital competence' has developed, and it is, according to Erstad et al. (2021), of fundamental importance to understand how digital competence is defined as a component of educa-

tion during the transition from the twentieth century to the twenty-first century. This article will begin by examining how digital technology and the term 'digital competence', as a central part of Norwegian curriculum, has developed since this term was introduced in the educational reform of 2006. This is followed by a systematic literature review presenting trends and development in research on digital competences among Norwegian pre-service teachers from 2000 to 2021.

1.1 Research questions

- How is the term 'digital competence' understood and operationalised in educational policy and research in Norway?
- What mean trends regarding the development and measurement of pre-service teachers' digital competence are found through reviewing the research literature from 2000 to 2021?

2 The position of digital competence in Norwegian education

Teacher education in Norway contains different programs aimed at different levels of the educational system, ranging from early childhood education for kindergarten teachers to various teacher programs for primary and secondary education. The approach to digital competence and its position in curricula and educational policy differ between these programs, but digital competence is highlighted as central and important across all programs.

2.1 Formal policy for early childhood education

Digital competence was first mentioned in the framework plan for kindergartens in 1995 and introduced as part of the chapter "Nature, environment and technology" in 2006 (Ministry of Education and Research, 2006a). In white paper number 41 (2008-2009), *Quality in kindergartens*, it is claimed that early childhood education is increasing the focus on subjects relating to primary and secondary educations' notion of basic skills, with this including the ability to use digital tools (The Norwegian Government, 2009). It is further stated that digital competence should be central to education at all levels and that children in early childhood education should come to view digital tools as a source of play, communication, and knowledge. In 2009, the Ministry defined the use of digital technology in early childhood education as a part of the quality- and innovation initiative in kindergartens (Ministry of Education and Research, 2009). The current framework plan for kindergartens (Ministry of Education and Research, 2017) has a stronger emphasis on digital technology and dedicates a section to digital practices under the heading 'work methods', which states the following:

> Digital practices in kindergarten shall encourage the children to play, be creative and learn. The use of digital tools must support the children's learning processes

and help implement the principles of the Framework Plan on creating a rich and varied learning environment for all children. (Ministry of Education and Research, 2017, p. 44)

The framework plan also provides guidelines stating that staff should be actively involved with the children when using digital tools. Furthermore, the digital practice must involve digital judgement, and staff must support the children to develop an early ethical understanding of digital media. Four bullet points are listed as mandatory guidelines for digital practice in kindergarten (Ministry of Education and Research, 2017, p. 45). Staff in kindergartens shall:

- exercise sound digital judgement with regard to searching for information, be conscious of copyright issues, critically analyse sources, and safeguard the children's privacy
- enable the children to explore, play, learn and create using digital forms of expression
- evaluate relevance and suitability and participate in the children's media usage
- explore the creative and inventive use of digital tools together with the children

Early childhood education in Norway has seven learning areas intended to promote well-being, all-round development, and good health: (1) Communication, language, and text; (2) Body, movement, food, and health; (3) Art, culture, and creativity; (4) Nature, environment, and technology; (5) Quantities, space, and shapes; (6) Ethics, religion, and philosophy; and (7) Local community and society. All learning areas are substantially the same as the subjects children will subsequently encounter in primary education and are to be recurring themes in the kindergarten content. The framework plan states that a range of technologies and digital tools are to be used when working with the various learning areas. Specifically, for the learning area 'Nature, environment and technology', it is stated that staff should use digital tools to inspire the children's mathematical thinking (Ministry of Education and Research, 2017).

The preparation of pre-service teachers for early childhood education
The kindergarten teacher education programme (referred to internationally as the early childhood education programme) is regulated through national curriculum regulations for kindergarten teacher education (Ministry of Education and Research, 2016a). It is comprised of six mandatory areas of knowledge, as well as specialisation and a bachelor thesis. The six areas of knowledge are (1) Art, culture, and creativity; (2) Children's development, play, and learning; (3) Nature, health, and movement; (4) Language, text, and mathematics; (5) Society, religion, beliefs, and ethics; and (6) Leadership, co-operation, and development.

The education of teachers for kindergartens must be in accordance with *The Kindergarten Act* (Barnehageloven, 2005) and the regulations of a framework plan for the content and tasks of kindergartens (Forskrift om rammeplan for barnehagens innhold og oppgaver, 2017). As stated in the regulations of the framework for early childhood education studies (2012, § 2), graduated students must have obtained a broad knowledge of children's beginning digital competencies. This means that digital com-

petency is seen as an integrated part of all learning areas in kindergartens and, subsequently, all areas of kindergarten teacher education programmes.

Kindergarten practices

The national report on ICT in Education, *Monitor 2019*, concludes that staff in kindergartens appear to have a good digital practice. The report describes a balanced use of digital technology in pedagogical work. Most staff perceive digital technology as a support that brings possibilities to their pedagogical practices, and a majority use digital technology on either a daily or a weekly basis. The reasons for using digital technology are the possibilities it creates in pedagogical work, as well as the fact that the curriculum makes it mandatory. The report also claim that staff have potential for improvement regarding how they are facilitating children's exploration, play, and learning, as well as facilitating children's abilities to create and express themselves through digital technology (Fjørtoft et al., 2019).

2.2   Formal policy for primary and secondary education

Regarding primary and secondary education, the official Norwegian report *Students' learning in schools of the future* (NOU, 2014) explains how digital technology has been an area of focus since the mid-1990s, with various strategies and plans for infrastructure, teachers' competence, and the use of certain software programs. As mentioned above, digital competence was formally introduced as a basic skill, one of five cross-curricular competencies listed in the educational reform in 2006. This makes digital competence part of all subjects at all levels of primary and secondary education in Norway (Ministry of Education and Research, 2006). In addition to formal curricula, the *Framework for teachers' professional digital competence* served as a guide for the teaching profession. This framework describes how important it is to highlight the significant role the teaching profession plays in the development of digitally competent students (Kelentrić et al., 2017).

In 2020, new curricula came into effect, representing a renewal of *the Knowledge Promotion*, which aims to give students more in-depth learning and better understanding of learning content. The renewal marked a shift toward more future-oriented perspectives, including twenty-first century skills, such as critical thinking, collaboration, communication and creativity (Keane et al., 2016). The amount of learning objectives is reduced to better facilitate in-depth learning. Three interdisciplinary themes are integrated in education to develop students' basic competence across subjects, and student participation is strengthened (Union of Education Norway, 2020). The three interdisciplinary topics are health and life skills, democracy and citizenship, and sustainable development. Digital skill, as a basic skill, is still to be incorporated into all subjects, but the subjects now have different roles and responsibilities in terms of the development of the five skills (Udir, 2021).

The preparation of pre-service teachers for primary and secondary education

The education of pre-service teachers for primary and secondary education is regulated through the *Framework plan for primary and lower secondary teacher education for years 1–7* (Ministry of Education and Research, 2016b) and the *Framework plan for primary and lower secondary teacher education for years 5–10* (Ministry of Education and Research, 2016c). Upon completing the primary and lower secondary teacher education programme, the requirements states that the graduates must be able to evaluate and use relevant teaching materials, digital tools, and resources in their teaching and to teach their pupils digital skills. The graduates must also be able to communicate on issues related to professional practice and possess digital skills appropriate to the profession (Ministry of Education and Research, 2016b, 2016c).

School practices

Regarding the pedagogical use of digital technology in schools, *Monitor 2019* reports that students in primary education interact with one another through learning games and quizzes but individual work in digital devices is the most widespread practice (Fjørtoft et al., 2019). This was critiqued in 2013, when the Digit-committee concluded that the practice in schools resulted in students who are able to use digital tools, but mainly as consumers (NOU, 2013). Some claim that this challenge is not merely related to digital practices but that Norwegian education positions the students as passive receivers of knowledge. Jordet (2020) claims that Norwegian school is characterized by a tradition that gives little room for children's relational, meaning seeking, creative, explorative, and intentional nature. According to the objectives of education and training, students 'must have the opportunity to be creative, committed and inquisitive' (The Education Act, 1998, § 1-1). Regarding the recent changes in Norwegian curricula, it is too soon to conclude how the renewal of *the Knowledge Promotion* will affect existing cultures in Norwegian education, but these changes are challenging the more traditional ways of teaching by highlighting the following:

> Creative abilities contribute to enriching society. Collaboration inspires innovation and entrepreneurship so that new ideas can be transformed into action. Pupils who learn about and through creative activities develop the ability to express themselves in different ways, and to solve problems and ask new questions. (The Directorate of Education, 2020, p. 7)

This concern is also addressed in *Professional Digital Competence Framework for Teachers*, which claims that 'it is more important than ever that children and young people are not merely passive consumers of products, services and information but also critical users and active producers of content themselves' (Kelentrić et al., 2017, p. 1).

2.3   From tool-oriented skills to cross-curricular competence

The report *Students learning in schools of the future* (NOU, 2014) states that, when digital competence was introduced as a basic skill along with *the Knowledge Promotion*, the original focus was students' ability to use digital tools. The following official

report *The school of the future – renewal of subjects and competences* states that digital development leads to changes in content and methods for all subjects in school. Digital competence has subsequently also come to be seen as a cross-curricular competence (NOU, 2015).

Competence in using a diversity of tools and competence connected to safety and security are examples of digital competence without any immediate connection to any of today's school subjects. Tool competence refers to the practical use of universal digital units and systems. Examples are using a computer and established software for word and number processing, presentations, and images, while security refers to e.g., learning how to protect one's own digitally stored information. As well as being a cross-curricular competence in itself, digital competence is also understood to be part of other cross-curricular competences, such as critical thinking, communication and collaborating. For example, today, critical thinking will generally be about assessing information, which is accessible digitally, and mastering digital tools and surroundings is an important part of communication and collaboration (NOU, 2015).

What began as a skill-oriented understanding in *the Knowledge Promotion* of 2006 has developed into a more complex concept of cross-curricula competencies. In the revised framework for basic skills from 2017, one finds a broader understanding of digital skills. In this framework, digital skills are defined as the ability to gather and assess information, be creative with digital resources, and digitally communicate and collaborate with others. This involves being able to use digital resources appropriately and in a safe matter to solve practical tasks, and digital skills includes the development of digital judgment by obtaining knowledge about and good strategies for online activities (The Directorate of Education, 2017).

Throughout the educational system, from early childhood education to secondary education, digital competence is seen as central. This is reflected in the preparation of Norwegian pre-service teachers. However, digital development is changing the educational context at a rapid pace, as well as our understanding and definition of digital competence. In Norway, several researchers have studied what professional digital competence entails for teachers (Gudmundsdottir et al., 2020), and in the newer literature, the term builds on a complex understanding of several competence areas (Brevik et al., 2019; Hatlevik & Bjarnø, 2021; Singh & Engeness, 2021). This complex understanding seems to be part of a certain Nordic interpretation of the conceptualisation of digital competence (Godhe, 2019).

2.4   The Nordic perspective

In a recent review of policy documents and relevant research in Norway, Finland, and Sweden, Erstad et al. (2021) conclude that digital competence has become a key area of importance in Norway. This conclusion is based in several national initiatives to promote digital competence in different educational settings. However, according to the authors, the field of research is still fragmented and varies in quality. Even though Norway is presented as one of the first countries to include digital competence as a core element in the national curriculum, there is, according to Erstad et al. (2021), a current lack of a national agenda for research on digital competence and no real re-

search base to inform practitioners and the development of policy. In Godhes's (2019) analysis of Swedish, Danish, Finnish, and Norwegian curricula, she found a common emphasis on societal issues and critical approaches. Godhe (2019) describes this emphasis as an indication of a certain Nordic interpretation of how digital competence is conceptualised. From a Norwegian perspective, this emphasis is evident throughout the mentioned framework for teachers' professional digital competence, as well as curricula and frameworks for kindergarten and primary and secondary education. This notion coincides with Erstad et al. (2021) analysis, in which they describe digital competence as central to contemporary curriculum development. The term 'digital competence' has developed into a complex concept, and from this development follows uncertainty concerning conceptual clarity (Erstad et al., 2021). The following systematic review regarding digital competence in teacher education in Norway contributes to a clearer understanding of the concept of digital competence in the education of pre-service teachers.

3   Methodology

A systematic approach to a literature review should 'provide an accurate account of the process that was undertaken to identify evidence for the review' (Booth et al., 2012, p. 80). Hence, this section provides a detailed description of how we arrived at our conclusions. This includes the setting of the inclusion criteria, the carrying out of the literature search, the selection of the articles, and the analysis of these articles. An overview of the database searches, with the details, number of results, and number of included articles, can be found in **Table 1**.

3.1   Inclusion criteria

According to the research questions, the aim of this literature review was to examine the empirical scientific literature published between 2000 and 2021 about Norwegian pre-service teachers' digital competence and the ways in which this has been measured. The articles had to report on research within a Norwegian context and be peer-reviewed to be considered. To further direct the literature search, we set these additional criteria for selection:

1. Pre-service teachers (qualifying for pre-school, primary or secondary school, or post-graduate teaching certificates) must be participants in the presented study.
2. The presented study must be related to pre-service teachers' digital competence/professional digital competence.

Table 1. Database search overview

Database	Search details	Number of results	Number of included articles
ERIC	("digital competence" OR "digital literacy") AND (Norway OR Norwegian) AND teacher AND student https://eric.ed.gov/?q=%28%22digital+competence%22+OR+%22digital+literacy%22%29+AND+%28Norway+OR+Norwegian%29+AND+teacher+AND+student Search performed on August 12 2021	15	3
Web of Science	(((ALL=(digital competence OR digital literacy)) AND ALL=(Norway OR norwegian))) AND ALL=(teacher student) https://www.webofscience.com/wos/woscc/summary/3306c8e8-f15e-47b4-9977-76c739fe2640-045adf43/relevance/1 Search performed on August 18 2021	90	12
Nordic Journal of Digital Literacy	("digital competence" OR "digital literacy") AND (Norway OR Norwegian) AND teacher AND student https://www.idunn.no/sok#?q=(%22digital%20competence%22%20OR%20%22digital%20literacy%22)%20AND%20(Norway%20OR%20Norwegian)%20AND%20teacher%20AND%20student&j=dk&p=1 Search performed on August 19, 2021	92	3
Science Direct	("digital competence" OR "digital literacy") AND (Norway OR Norwegian) AND teacher AND student https://www.sciencedirect.com/search?qs=%28%22digital%20competence%22%20OR%20%22digital%20literacy%22%29%20AND%20%28Norway%20OR%20Norwegian%29%20AND%20teacher%20AND%20student&date=2001-2021&show=100&lastSelectedFacet=articleTypes Search was also refined with filter for only Review articles and research articles Search performed on August 22, 2021	133	4
Total number of included articles			**22**

3.2   Literature search

Search of databases

Furthermore, the selected search terms were used in searching three different scientific databases (see **Table 1**). These were chosen because they index highly recognised journals in the field of education, in which most Norwegian studies of significance are likely to be published. In addition to the three international databases, we

searched specifically within the *Nordic Journal of Digital Literacy*, which is a Norwegian scientific journal specialising in this field and therefore relevant. On *Web of Science*, we made use of the advanced search option to add and combine separate search criteria. A similar procedure was used for the other database searches by applying Boolean operators (see https://eric.ed.gov/?advanced and https://service.elsevier.com/app/answers/detail/a_id/25974/supporthub/sciencedirect/). The time frame (2001–2021) was also added or checked manually.

Article selection
The next stage of the process was selecting articles for the review by reading the abstract of each article and evaluating this according to the initial criteria. Each search and evaluation were documented according to the procedure shown in **Fig. 1**. During this search stage, 25 articles were included for further assessment. Later, through a more in-depth reading of the articles, three articles were reconsidered and found not to meet the criteria. Hence, the final number of included articles was reduced to 22.

Fig. 1. Article selection procedure
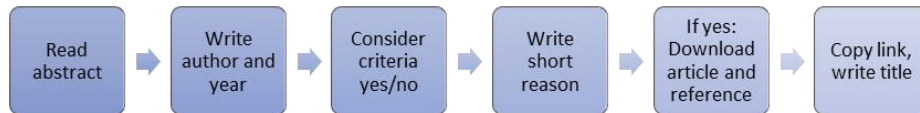
Initial search
To obtain an overview of the field and identify suitable key words, we performed an initial scoping search. The variety of terms characterising the field made the selection of the search terms difficult. Digital competence is also referred to as skills or literacy, and within the target population, there are students from various teacher programs. Moreover, different terms are used for such students (e.g., pre-service teachers, student teachers, teacher students, and pedagogical students). This made the search process complex.

Table 2. Initial search overview

Database	Search phrase	Number of results
ERIC	professional digital competence Norway	224
	digital literacy + Norwegian	5
Web of Science	Digital competence Norway	204
	professional digital competence Norway	5

One way to avoid excluding any teacher education programs was to solely search with words identifying digital competence and the location of Norway. We attempted this with various combinations in two databases, *ERIC* and *Web of Science* (see **Table 2**). One challenge was that the search either returned too few results or too much material outside of our scope. However, we found that in relevant articles the terms 'student

teacher' and 'teacher student' seemed to be frequently used, and 'teacher' and 'student' were therefore chosen as search terms. We also decided to retain both 'competence' and 'literacy' because, though the first term is more common in Norway (Røkenes & Krumsvik, 2016, p. 2), they are both frequently used in the research literature. Hence, after this initial search stage, we considered the following list of search terms expedient to proceed with: 'digital competence', 'digital literacy', 'teacher', 'student', 'Norway', and 'Norwegian'.

3.3   Analysis

The next step was to assess each article more thoroughly according to the aims of the study. This was done by setting up a scheme as shown in **Table 3** and performing a targeted reading of relevant sections in the articles. The main focus was to identify the results regarding Norwegian pre-service teachers and their digital competence, as well as what methods were used to measure this. Some of the articles also included other units of analysis in addition to student teachers (e.g., other nationalities, teacher educators, and institutions), and in such cases, these units were ignored. In the table, we also included columns for the target teaching level (i.e., which education level the pre-service teachers will qualify to teach after graduation) and what theoretical framework or model was applied. Lastly, a column with short descriptions of the digital competence areas included in or the emphasis of each study was added. Investigating what the research focused on, there were not very apparent categories. However, some loose thematic categories were applied.

Some of the information in the table was also counted and checked more thoroughly in a spreadsheet (e.g., the number of articles with certain methods, theoretical frameworks, and school level), which is accounted for in section 4, Results and discussion. A first impression from this phase indicated the sequential emerging of a broader and more complex concept, as well as that both theory and definitions had matured during the period we are examining. However, this situation had to be investigated in more detail, and through the next stages, we sorted the articles chronologically, searched for definitions, and added these definitions to the column 'Theoretical framework / digital competence definition or model'.

To further ensure the validity of the findings, a more thorough reading of each article was performed. This led to some corrections and updates to the findings table, as well as a clearer view of the anticipated concept development.

Table 3. Literature analysis results overview

	Title, authors, year	Target teaching level (pre-school, primary, secondary)	Methods, type of study	Theoretical Framework / Digital competence (DC) definition or model	Results, implications	Digital competence area/emphasis
1	Videopapers – an attempt to narrow the notorious gap between theory and practice in teacher education (Krumsvik & Smith, 2009)	Teacher students one-year post-graduate teaching certificate grade 8–3 (n = 6)	Qualitative Small (pilot) case study Structured interview	Lack of explicit DC definition Tool/skill-oriented focus pedagogical and didactical use of ICT	Video papers make required reading more enriching and less tiring VP speaks to the digitally literate generation of students and provides 'hands-on' experience with ICT and multimodality, which may increase digital competence	Tool use/digital practice
2	Educating Teachers for the New Millennium (Tømte, 2013) (Originally 2013, reprint in special issue 2015)	3 teacher education institutions, teacher students for grades 1–10 (n = 54) teacher educators (n = 27), program managers (n = 23)	Qualitative Multiple case study Document analysis, interviews with management, teacher trainers, and student-teachers	Refers several generic DC definitions and concept development but does not explicitly approve of any Digital Competence is the set of knowledge, skills, attitudes (thus including abilities, strategies, values and awareness) that are required when using ICT and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autono-	Identifies an increasing awareness of the use of ICT in education from 2009 to 2012 Teacher students are not sufficiently well prepared to use ICT for pedagogical purposes through their ITE	Equipment situation Mastery of software and ICT tools

				mously, flexibly, ethically, reflectively for work, leisure, participation, learning, socializing, consuming, and empowerment (Ferrari, 2012, p. 3). It corresponds to what has been the dominant understanding of digital competence in Norway, as communicated as early as 2005 by the National Network of ICT in education: "Skills, knowledge, creativity and attitudes required to be able to use digital tools in learning and living in a knowledge society" (ITU, 2005)		
3	Social Networking Sites in Education – Governmental Recommendations and Actual Use (Helleve et al., 2013)	Preservice teachers in years 3 and 4, post-graduate certificate from 6 teacher education institutions, grades 11–13 (n = 474) (Study 1 of 2)	Quantitative Questionnaire	Digital competence mentioned as one of the five basic skills, but no explicit definition Digital media ethics (Ess, 2009)	Pre-service teachers report negative attitudes toward the use of Social Networking Sites for communication between teacher-pupil. They don't use SNS for pedagogical purposes	Responsible ICT use Social networking sites/ Social media Digital media ethics
4	Development of Student Teachers' Digital Competence in Teacher Education - A Literature Review (Røkenes & Krumsvik, 2014)	Teacher students qualifying to teach in the secondary school level Grade 8–13	Qualitative Literature review Thematic analysis	Several DC definitions mentioned (e.g., Ferrari 2012, ITU 2005) Krumsvik's definition of professional digital competence: "the teacher's… proficiency in using ICT in a professional context with good pedagogic-didactic judgment and his or her awareness of its implications for learning strategies and the digital Bildung of pupils and students" (Krumsvik, 2011b, pp. 44–45)	Identified 8 approaches used by teacher education programs to develop DC in student teachers (collaboration, metacognition, blending, modeling, authentic learning, student-active learning, assessment, and bridging theory/practice gap) Only 2 studies from	Broad Pedagogical use of ICT

					Norwegian context, of which 1 (Krumsvik & Smith, 2009) is already included in this review	
5	Appropriation of Digital Competence in Teacher Education (Instefjord, 2014) (Originally 2014, reprint in special issue 2015)	Pre-service teachers, 1st and 2nd year (n = 14) Grade 1–10	Qualitative Multiple case study (2 cases) Focus group interviews	Learning as situated process (Somekh, 2008) Mastery and appropriation (Wertsch, 1998) Mentions several broad definitions (Ferrari, 2012; Ng, 2012; Krumsvik, 2011) Focus in article on DC as a tool for teaching and learning	Students rate their own levels of digital competence as high, and acquired such before starting the program. PDC training is detached from the remainder of subjects, identifying a need for more integration	Tool use for teaching and learning Digital practice Interactive whiteboards
6	Educating online student teachers to master professional digital competence: The TPACK-framework goes online (Tømte et al., 2015)	Online teacher students (n = 96) grade 1–7 and 5–10	Mixed methods Case study Survey of students Group interviews	Brief overview of international development of the concept, mentions Krumsvik's definition (see above) but leans mostly on the TPACK-framework (Koehler & Mishra, 2006) as an important avenue for understanding teachers' abilities to combine diverse fields of competence.	Few results regarding students presented in the article Online learning provides opportunities for teacher educators to act as role models in integrating ICT	Online learning
7	Expressing Professional Identity through Blogging - A Case Study of Blogging in the Study of the Sub-	Pre-school teacher students 3rd year (final semester) (n = 8) Grade pre-school	Qualitative Case study, text analysis	Theories of professional identity New media literacy theory Lacks explicit DC definition but highlights the need for research on the subject-specific use of ICT	Digital practices in teacher education must be connected to specific subjects and contextualised according to overall aims Comments on the few	Tool use/digital practice Blogs

	ject of Norwegian in Pre-School Teacher Education (Kvåle & Rambø, 2015)				studies of ICT in Norwegian pre-school teacher Education	
8	The use of flipped classrooms to stimulate students' participation in an academic course in Initial Teacher Education (Helgevold & Moen, 2015)	Teacher students, course in *Philosophy of science and research methods* (n = 81) Grade ?	Mixed methods Semi-structured questionnaire (n = 81) Interviews (n = 5) Analysis of students' written texts (n = 107)	Student-centered learning (Bishop and Verleger, 2013; Piaget, 1967; Vygotsky, 1978) Socio-cultural perspectives Digital competence mentioned as one of the basic skills, no explicit definition Pedagogical use of ICT	FC perceived good for Preparing (online lectures + writing) Stimulated involvement Variation in modalities Relevant to future teaching practices Varying how students perceived group work on campus	Tool use/digital practice Flipped class-room
9	Participant activity and facilitator strategies in an LMS-based discussion forum (Strømman, 2015)	Student teachers Grades 1–7	Qualitative Interpretative Analysis of written data from discussion forum Interviews	Research-based theory on discussions forum Lack of DC definition. The word 'digital competence' is not used, but the practice investigated is described as practice and also related to the ways student teachers are expected to engage in collaborative activities and use digital strategies in their future work as teachers	Implications for increasing activity in online forums Students, though used to social networking sites, do not engage accordingly in LMS (learning management system- based discussions; it is considered a 'school genre'	Tool use/digital practice Online interaction
Break 1 (2014-2015): From a perspective concerning digital support for traditional pedagogy toward digital competence as a more complex concept challenging the premises of teaching						
10	Prepared to teach	Postgraduate student	Mixed methods	Theoretical model of digital competence devel-	Showing practice	Broad PDC

	ESL with ICT? A study of digital competence in Norwegian teacher education (Røkenes & Krumsvik, 2016)	teachers (specialising in English as second language, ESL) Grades 8–13	Case study Local Participant observations (n = 18–20) Two surveys (n=41, n=112). Semi-structured interviews (n=15).	opment (Krumsvik) Two axes: Self-awareness and practical proficiency Four core components: - Basic digital skills - Didactic ICT competence - Learning strategies awareness Digital Bildung	examples from ITE, specifically at a micro-level	development factors (modelling, scaffolding learning experiences, linking theory and practice, reflection, access to resources and support, innovative assessment practices, and collaborative learning) Student teachers' self-perceived digital competence
11	Introducing Blended Learning MOOC – A Study of One bMOOC in Norwegian Teacher Education (Langseth & Haugsbakken, 2016)	Online teacher students n = 256 grade ?	Mixed methods LMS data on user participation Qualitative interviews semi-structured	Connectivism DC (uses the term digital literacy) definition from Martin (2006): "The awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyse and synthesise digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action; and to reflect upon this process" The article focuses on tool-use, developing DC through use, and trying new technology	Questions whether teacher students have enough digital competence to make use of online learning objects in formal learning (see p.68) (Digital natives myth)	Online learning Online cooperation Connectivism MOOC

12	What's in a wiki? (Brox, 2017)	Student teachers, undergraduate 3rd year, subject Norwegian (n = 13) grade ?	Qualitative Case involving the use of wikis Semi-structured interviews Analysis of logs from the project	New materialism (Coole & Frost, 2010; Pötzsch, 2017) Actor-network theory (Latour, 2007) Lacks explicit DC definition but discusses other DC studies and criticises a tools-based understanding The article reports on a larger study, with a focus on how wikis could function as a tool for learning and enhance students' digital competence, but it adopts a more critical and wider perspective on technology than "supporting and enhancing" learning. Broader discussion of human-technology relations using theories that question a one-way understanding of agency, artifacts, and affordances, (e.g., technologies not neutral, inherent agency of software and algorithms)	Student teachers unable to connect experiences with the digital tool to concepts such as digital competence and learning outcomes Theoretical implications: questioning the tool metaphor in understanding human-technology relation	Tool use/digital practice Wikis Theoretical discussion about technology as something more than a tool
Break 2 (since 2017): Professional digital competence as a distinct concept is broadly applied						
13	Educating digitally competent teachers: A study of integration of professional digital competence in teacher education (Instefjord & Munthe, 2017)	Pre-service teachers, 4th year (final or first year of MA) Grades 1–10 (n = 654) (Student teachers only part of the study, which also included teacher educators (n = 387), mentor teachers (n = 288))	Quantitative National questionnaire Descriptive and explanatory analyses	DC definition: "Being able to integrate and use technology for educational purposes involves having a set of generic skills suitable for all situations, both personal and professional, as well as specific teaching-profession skills. This is what is referred to as professional digital competence for teachers" (article refers to Lund et al. (2014)) Mentions several theories of technology integration	Student teachers are critical of the ICT/DC component of education but have favourable opinions of their own competence	Tool use Technical, pedagogical, ethical
14	Newly qualified teachers' profes-	Newly qualified (0–2 years)	Quantitative National survey	Theories about ICT self-beliefs; ICT self-efficacy, perceived usefulness of ICT, perceived	Perceived poor quality/contribution from	Self-efficacy Perceived

	sional digital competence: implications for teacher education (Gudmundsdottir & Hatlevik, 2018)	Grades 1–10 (n = 356) Questions about initial teacher education	Country case Self-reports	PDC developed through ITE Professional Digital Competence three pillar (dimensions) model, inspired by TPACK framework but including a specific profession-oriented aspect of PDC: 1. Generic digital competence, which cuts across disciplines and specifies general knowledge, skills, and attitudes that teachers, teacher educators, and student teachers require in order to teach and learn in digital environments. 2. Subject/didactic digital competence, which captures what is specific to each subject when taught with and through ICT. 3. Profession-oriented competence, which includes various aspects related to and supporting teaching in technology-rich environments. This pillar includes 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 (Gudmundstdottir & Ottestad, 2016)	ICT training during ITE 80% positive beliefs about ICT Negative beliefs about distractions from ICT	usefulness of ICT
15	Transformative agency in teacher education: Fostering professional digital competence (Brevik et al., 2019)	Student teachers, 6th term of ME programme Online course (n = 139) Grade ?	Mixed methods Digital traces in course (n = 139) Survey (n = 92) Focus group interviews (n = 12)	Uses the PDC three pillar model (Gudmundsdottir & Hatlevik, 2018) and adds a fourth dimension, *Transformative digital agency* Transformative digital agency "captures (student) teachers' competence in taking initiatives and transforming their practices by selecting and using relevant digital tools. It arises as a necessity when (student) teachers are placed in demanding situations involving challenges or a conflict of motives, thus creating a wish or need to break out of the current situation" ((Brevik et al., 2019, p. 4). Article also refers to understanding of PDC	Student teachers actively sought to resolve demanding situations by going beyond their current PDC through engaging in diverse forms of transformative agency (selecting and using relevant digital tools) SPOC was helpful in this matter	Digital agency (see p.4) Digital practice: SPOC (small private online course thematically focused on PDC)

				derived from Lund et al. (2014)Transformative agency (Virkunnen, 2006) Principle of double stimulation (Vygotsky, 1978)		
16	Becoming a professional digital competent teacher (Helleve et al., 2020)	Teacher students in last part of education and newly qualified teachers (n = 7) Grade ?	Qualitative Comparative study Case study Semi-structured interviews (n = 7) (Participants recruited from earlier in the study: Paper-based questionnaire (n = 475) and Web-based questionnaire (n = 35)) National	Lacks explicit DC definition but refers to an understanding of PDC from Lund et al. (2014): "Comprising a deep understanding of technology, knowledge of students' learning processes, and an understanding of the specific disciplinary practices and features characterizing individual school subjects." Also includes some aspects of the *Professional Digital Competence Framework for Teachers* (Kelentrić et al., 2017): "the ability to design learning processes through learning objectives, to choose the means and types of evaluation, and to select the appropriate technology to support this relationship"	SNS used mainly for social reasons Awareness of challenges Negative to use for pedagogical purposes because of privacy issues Need for reflections and awareness in ITE	Social networking sites Digital media ethics
17	An analytical unit of transformative agency: Dynamics and dialectics (Lund & Vestøl, 2020)	Student teachers in a five-year master's program (n = 195) Grade ?	Mixed methods Report from an intervention to foster PDC Survey Assignments Group interviews (article reports mostly from these)	Cultural-historical activity theory PDC involves linking digitalization to epistemology, pedagogy, subject didactics, and professional endeavours, such as class management and connecting academic and experience-based knowledge (Lund et al., 2014) Links to (Brevik et al., 2019) and the adding of a fourth dimension to the three-pillar PDC model.	64% reported the intervention developed their PDC (the article is more theoretical/methodical, with empirical examples)	Transformative agency Navigating online information, finding relevant research
18	Student teachers' responsible use of ICT: Examining two samples in Spain and Norway	First-year student teachers Grades 1–10 and 8–13) (n = 563)	Quantitative Survey Scales for perceived competence in privacy issues and han-	Refers to several studies and highlights the aspects of DC regarding digital judgement, risk evaluation, understanding the role of digitalisation in a democracy, evaluation of digital content, and being a responsible citizen.	Norwegian teacher students perceive themselves as competent in the three areas (privacy issues [PI], cyberbullying [CB],	Responsible use of ICT, three concepts: Privacy issues Cyberbullying

	(Gudmundsdottir et al., 2020)	(The study also included students in Spain (n = 681))	dling cyberbully-ing adapted from 2013 International Computer and Information Liter-acy Study (ICILS) questionnaire Scale for ability to evaluate digital content adapted from Norwegian Monitor Study 2011 Self-reporting	These are also aspects of PDC The study draws on two PDC models. - the three-pillar model (+ 4th pillar, digital agency) - the PEAT-model for PDC developed by the DICTE-project (Dicte, 2019) (4 dimensions: pedagogical, ethical, attitudinal, technical) Emphasises the attitudes and ethics dimensions	and the ability to evaluate digital con-tent [EDC]) Relationships between the three concepts evaluated. Strong relationship: PI–CB Moderate relationship: PI–EDC Weak relationship: EDC–CB	Ability to evaluate digital content
19	Perspectives on the tensions in teach-ing with technolo-gy in Norwegian teacher education analysed using Argyris and Schön's *theory of action* (Thorvaldsen & Madsen, 2020)	Fourth-year mas-ter's students in teacher education Grades 1–7 and 5–10 (n = 48) (study also included teaching staff, n = 64)	Quantitative Local survey University case Questionnaire (digital, Quest-back) Students' self-reports Statistical analysis (n = 112, includ-ing staff)	Theory of action, Argyris and Schön (1978) PDC with three aspects: pedagogic and didactic understanding subject-specific understanding technological understanding (Operationalisation of Tømte & Olsen, 2013 og Lund et.al. 2014) Also corresponding with TPACK's three components; content, pedagogy and technology	Staff have better PDC than students, but students have a more positive attitude Leads to differences in what impacts the use of digital tools	Professional attitudes Application of tools
20	Students' percep-tions and use of a new digital tool in teacher education (Bader et al., 2021)	Student teachers specialising in English as a foreign language Grades 5–10 (n = 40)	Qualitative Intervention study Students' respons-es/attitudes toward and use of the tool 128 reflection notes by 40 stu-dent teachers	Cultural-historical theory Formative assessment PDC definition: Students' attitudes to and actual use of digital technology are seen as contrib-uting to a more nuanced understanding of stu-dents' digital competence, as well as their actual use. The authors build on Lund et al. (2014) and state that professional digital competence in-	Students' attitudes and use are related to perceived ease of use, not the learning-related potential of digital technology	Tool use/digital practice: *OneNote Class Notebook* Attitudes Use

			Focus group interview, 3 students	volves teachers not only appropriating technologies but also making their learners appropriate them and put them to productive use Includes newer development of PDC understanding involving digital agency and "PDC as an agentive, quality and context sensitive as well as transformative capacity" (Aagaard & Lund, 2020)		
21	Student teacher podcasting: Agency and change (Carson et al., 2021)	Student teachers (n = 2) (60 podcast episodes created by the two, with guests, among them 52 other students) Grade ?	Qualitative Interaction analysis - Observation - Analysis of content and dialogues	Sociocultural approach Agency (Emirbayer & Miche, 1998) Dialogic spaces Lacks explicit PDC definition but mentions Koehler and Mishra (2009) and Lund et al., (2014) Connects the study to recent theoretical development linking PDC to digital agency / agentic learning (see other studies in this review)	Working with/producing podcasts can provide opportunities for agentic learning	Agency Digital practice – podcasting
22	Examining the relationship between resilience to digital distractions, ICT, motivation, approaches to studying, and time spent on individual studies (Hatlevik & Bjarnø, 2021)	Student teachers, year 1 Grades 1–7 and 5–10 (n = 219)	Quantitative Questionnaire (study evaluation with added extra questions)	Lacks explicit PDC definition but addresses factors such as classroom management and coping with the challenges imposed by digitalisation. Resilience Self-regulation Self-efficacy (Bandura, 1997) (could be understood as aspects of a broad DC/PDC understanding/definition)	Motivation, resilience to digital distractions, and gender positively correlated with approach to studying Students report high self-confidence in the use of digital tools	Resilience to digital distractions ICT self-efficacy Classroom management

3.4 Reflections and limitations

To ensure transparency, the following section will provide an account of the challenges faced, changes that had to be made once the project was underway, as well as the general limitations of the study.

In the literature search, we originally stipulated that articles must provide information regarding methods for measuring digital competence. Due to the range of methodological approaches in the literature, we decided it would be better to evaluate this after the selection of the articles. Furthermore, the chosen search terms originally included 'pre-service teacher' and 'pedagogy', but it soon became clear that these did not provide additional relevant results and would be redundant.

The choice of databases to search may have excluded some contributions. Firstly, searching three international databases with English search terms entails the exclusion of articles written in Norwegian. Likewise, by limiting the search to online journals, literature published in books would fall outside of the scope. Nonetheless, publishing internationally is common in the Norwegian research community, and it is reasonable to assume that important research contributions would be found in these channels. The book *Digital læring i skole og lærerutdanning (Digital learning in school and teacher education)* (Krumsvik, 2016) is comprised of contributions from several of the authors represented in this review, presenting the same or closely related content in Norwegian, an indication that the selected literature is representative.

During the analysis of the material, steps were taken to avoid a thematic bias toward schoolteachers and verify the finding that there are few articles on pre-school teacher education. Two control searches were performed within each database, with the search terms 'Early childhood education' and 'Preschool teacher student' replacing student teacher. The search did not return more relevant results, except for one article. This was first added because of its relevant topic but later excluded due to the empirical criterion. There is, however, also a chance that more research in this specific field is prone to being published in Norwegian.

A complete categorisation according to school level was difficult to obtain. Firstly, some articles did not explicitly state their target teaching level. Furthermore, both historically and organisationally, there are differences between teacher education programs, especially regarding the intersection between upper and lower secondary school. However, one indicator of level is that master's programs are aimed at primary and secondary school, while pre-school teacher is a 3-year bachelor's education.

Two of the articles that were originally included with publishing year 2015 were ultimately revealed to be reprints (Instefjord, 2014; Tømte, 2013). This caused some difficulties regarding the question of how to interpret the chronological development of concept understanding, but the larger trends discussed seem to remain the same.

When we turned our attention toward concept development, the choice to focus strictly on empirical research created some challenges. Among the references listed in the selected articles, we discovered some purely theoretical articles that were important for understanding this development and decided to read and comment on some of these as part of the discussion. This investigation could even have been elu-

cidated by studies of in-service teachers or the compulsory school level. We chose, however, to keep the discussion limited to the realm of teacher education.

4   Results and discussion

The present literature is, on many levels, a varied selection of articles regarding methods, thematic emphases, theoretical underpinnings, and which teacher programs the studies report on. Although the topic of digital competence and student teachers has guided the selection process, the research questions differ extensively within the selection of articles, and the link to the term 'digital competence' is not always explicit or clear. Hence, in some cases, it is not the main findings in the studies that are the most interesting for this review but, rather, the 'side-findings'.

In the following, selected findings will be elaborated and discussed. For a more detailed account of each article, see **Table 3**. We begin by presenting the different target teaching levels, and here, a significant imbalance in the literature must be commented on. Following this, a review of the methods provides an account of some attempts to measure digital competence, as well as showing the variety of such approaches. An introductory discussion of language and metaphors is also included. Next follows a short account of theoretical foundations, which provides fundamental information with which to understand the last and most extensive section, that presenting and discussing the concept development.

4.1   Target teaching levels

All the articles report on studies in which student teachers play a part, though they are not always the main focus. Concerning which grade the students are qualified to teach, ten studies address programs qualifying to teach at the compulsory school level. Only five of the studies address teacher education programs aimed at teaching grades 8–13, which corresponds with the lack of studies addressing such grades mentioned by Røkenes and Krumsvik (2014). Seven articles that do not explicitly state which levels they report on make these conclusions less certain.

However, what stands out as most striking is the low number of studies regarding pre-school teacher education, that is, only one of the selected articles. There are no indications in the articles not specifying school level that they report on this field either. This is also confirmed by the authors of that one article when they write that "there are still few studies on the uses of ICT in Norwegian *pre-school teacher education*" (Kvåle & Rambø, 2015, p. 8).

Thus, digital competence in early childhood teacher education appears to have been less in focus, at least in the English peer-reviewed literature. Kvåle and Rambø (2015), reporting on the use of blogging in a course in Norwegian, do not define PDC but connect with the field through mentioning the 'growing research interest in the uses of ICT in Norwegian teacher education' and referring to other relevant articles. There is also a link to the PDC models presented in other articles, stressing the importance of relating ICT use to specific subjects.

Bølgan (2012), the additional result of the above-mentioned control searches, does not report empirical studies on student teachers but still provides important information about the development in the field of ICT in kindergartens and related education programs in Norway. In an extensive review of history and policy documents, Bølgan paints a picture of a field in progress. However, there are indications that ICT in early childhood education and early childhood teacher education has lagged behind other parts of the education system. The author calls for a greater inclusion of early childhood education in national ICT strategies (Bølgan, 2012, p. 164). The article also presents a view of digital literacy as more than ICT skills and is thus in line with much of the other literature presented in this review. Considering the time that has passed since it was written as well as the development in policy described in the first part of this article, the lack of research articles in this area is striking. This lack may be due to it being a young research field or lacking a tradition of international publication. Nonetheless, the need for more development and research in the field of ICT and early childhood teacher education pointed out by Bølgan (2012) is still evident and also corresponds with recent investigations in the field (see Fjørtoft et al., 2019).

4.2   Methods used in selected articles

Concerning methodology, there was a majority of purely qualitative studies (10), and slightly fewer relied solely on quantitative methods (6). However, the number of studies applying various sorts of mixed methods (6) makes this difference less distinct. It may be more correct to say that the articles show a great deal of variety in their methodological approaches. In the quantitative approaches, the measurement seems to rely mostly on the self-reporting of perceived competence or attitudes.

Among the quantitative studies, including those with mixed methods, only a few attempt to specifically measure digital competence as an overall concept. The studies that have most explicitly developed items for measuring teacher students' overall professional digital competence are Røkenes and Krumsvik (2016), Instefjord and Munthe (2017), Gudmundsdottir and Hatlevik (2018), and Thorvaldsen and Madsen (2020). In reading the descriptions of the methods and questionnaires used, two observations stand out. Firstly, measurement is mostly performed through the self-reporting of elements such as skills, usage, and attitudes. Secondly, wordings such as 'use of digital tools' and 'use of ICT' are repeatedly used, though in combination with words and phrases such as 'pedagogical', 'didactical', 'for learning', and 'for teaching'. How this relates to a broad or narrow understanding of digital competence will be discussed below. Tømte et al. (2015) include two items concerning students' digital literacy and students' social lives on the Internet but do not document which questions these consist of. Other quantitative studies have measured more specific areas within professional digital competence. Helleve et al. (2013) report from a study on social networking sites (SNS) and focus on the ethical aspect of digital competence. To measure these aspects of digital competence, the survey asks questions about the SNSs applied, the frequency of use, the motivation for use, as well as prospective actions after being qualified as teachers. Another study that delves into the ethical component of digital competence is Gudmundsdottir et al. (2020) article on student

teachers' responsible use of ICT. The items investigated are 'perceived competence in privacy issues', 'perceived competence in handling of cyberbullying' and 'ability to evaluate digital content' (Gudmundsdottir et al., 2020, p. 8). Hatlevik and Bjarnø (2021) do not describe their research as being about digital competence, but it still includes two items that describe relevant aspects of such. These are 'resilience to digital distractions' and 'ICT self-efficacy'. Other authors use the quantitative approach to measure other aspects relevant to the study, e.g., the evaluation of courses or work form (Helgevold & Moen, 2015; Langseth & Haugsbakken, 2016; Lund & Vestøl, 2020), and the quantitative sections of these studies are thus less relevant to this discussion.

The qualitative studies do not measure student teachers' digital competence. Rather, they illuminate and discuss the concept from different angles, as well as showing how teacher education may contribute to the development of such competence. Three of these articles more clearly seek to develop the concept and they apply methods such as document analysis, interviews, and literature reviews (Instefjord, 2014; Røkenes & Krumsvik, 2014; Tømte, 2013). However, the majority (7) of the purely qualitative studies report on specific digital practices or the applications of digital tools, e.g., videopapers (Krumsvik & Smith, 2009), blogging (Kvåle & Rambø, 2015), online discussion forums (Strømman, 2015), or podcasting (Carson et al., 2021). Røkenes and Krumsvik (2014) pointed out that previous reviews and studies had lacked in the area of 'micro- or interactional levels focusing on showcasing daily teaching practices and activities with ICT' (p. 251). The many examples of such approaches in this review indicate that the research community in Norway has responded to this situation. The methods used vary, but they are mainly traditional qualitative approaches, such as interviews (individual and focus group), observations, as well as the analysis of written data.

The tool metaphor used in the quantitative and mixed-methods studies described above also frequently appears in the qualitative studies. Firstly, this is visible in the fact that some sort of digital tool and its use in an educational setting is the topic or object of interest in most studies. Furthermore, when considering language and formulations, both in the discussions of findings and the questions asked in interviews or surveys, a focus on the use of digital tools prevails to a large degree. This is also the case for studies applying mixed methods, as shown above.

Some studies are also exploring the possibilities in digital technologies for generating data (e.g., online written material such as wikis or discussion forums and video and sound recording). This is relevant to the topic of digital competence and may represent an underutilised resource that might shed light on findings from self-reported data in quantitative surveys or interviews, either confirming or correcting them. The reflections of Brox (2017, p. 139) on the discrepancy between data derived from digital practice and data derived from interviews may serve as an example of this.

4.3 Theoretical foundations

In addition to articles using different versions of the term 'digital competence' as their main theoretical framework, many different theoretical perspectives are used in the literature. This seems to be related to the different research focuses. Some articles apply theory concerning the specific theme or object of the study (e.g., self-efficacy and digital media ethics), while others apply theories to understand the implementation of ICT or digital competence (e.g., mastery and appropriation, TPACK espoused/in use, theory of action)

However, one theoretical tradition that stands out as remarkably more frequent than any other is socio-cultural theory. Some articles state this quite explicitly (E.g., Brevik et al., 2019; Helgevold & Moen, 2015), and the influence of various members of this theoretical family has served as the foundation for the most commonly used models and definitions of PDC developed in Norway (Krumsvik, 2011; Lund et al., 2014). The same is the case with the earlier development of digital competence in compulsory school (Erstad et al., 2005), which has influenced more recent work regarding teacher education.

4.4 Digital competence concept development

A great deal of work in this field seems to be more focused on conceptualising and developing a definition of digital competence than on measuring it. Introductions, theory sections, and discussions contain many references to others work, as well as the authors' own attempts. Some explicitly write themselves into the ongoing development of PDC, while others may be understood as such due to the closely related theme or research object.

Several definitions and models are thoroughly presented in the articles covered by the review. However, theoretical and conceptual discussions and development apparently do not always appear in reports on empirical work. Hence, some important foundational articles have been excluded. To complement the discussion, we will comment on some of these, as well as providing some contextual information, in the following presentation.

ICT and technology tools, 2001–2009

In approaching the articles chronologically, the first finding is the nearly 'non-finding' of articles from the first half of the time span. The earliest published article included in the review is from 2009, and it is not until 2013 that regular publications on the topic appear. This lack of earlier articles is probably due to the way in which we narrowed down the literature search and chosen search terms. Searching for ICT or technology in teacher education may have returned more results. Nonetheless, regarding the focus on concept development, it is perhaps an even more relevant finding that, at an early stage, the term is hardly used at all. There are also indications of this in the literature, both through the references and in repeated descriptions of a field focused on technology and ICT in itself, as opposed to progress toward viewing it in relation to pedagogical or didactical objectives.

ICT as tool for teaching and learning, 2009–2015
In articles from this period, different international definitions and frameworks are frequently referred to, particularly Ferrari (2012), with a more general definition, and Koehler and Mishra (2009), with their teaching-oriented TPACK-framework. Another common point of departure is to connect this research area in teacher education to the introduction of digital skills into the Norwegian curriculum for compulsory school. In addition to international studies, the work of the Norwegian scholar Rune J. Krumsvik begins to gain some attention.

Explicit definitions of digital competence are either lacking (Helgevold & Moen, 2015; Helleve et al., 2013; Krumsvik & Smith, 2009; Kvåle & Rambø, 2015) or become unclear in the presentation of multiple perspectives (Instefjord, 2014; Røkenes & Krumsvik, 2014; Tømte, 2013). Still, the studies from this period reveal that the understanding of digital competence in the field is in a process of maturing, from one with a limited focus on learning to use digital tools into a more pedagogical orientation stressing that digital tools should support teaching and learning.

Towards a broader concept understanding, 2014–2017
There is no clear cut in this case, but during 2014 and 2015, a break in how the terms are used and applied seems to appear, moving toward a more complex and broader concept. The scholarly debate on concept development gains momentum, and a lot of work is done in a relatively short time span, visible in an increasing number of relevant findings in the literature search. There is a clearer awareness of the need to specify and define digital competence when studying it, as shown most clearly in Røkenes and Krumsvik (2016) application of one theoretical model of digital competence as an analytical lens in their study.

Krumsvik has published extensively in the field of digital competence, and was early in proposing how to define the concept, both in a general educational setting and in relation to teacher education (Krumsvik, 2008). The model was further developed in several articles (Krumsvik, 2008; 2011; 2014). In addition to elaboration in his own work, the model and concept definition also inform and inspire other studies. Though frequently cited (six times in this review), this definition seems not to have had the same practical impact as others. The model has several theoretical foundations, among them the TPACK framework and sociocultural learning theory, especially situated learning, and describes four components of digital competence: *basic digital skills*, *didactic ICT-competence*, *learning strategies*, and *digital Bildung* (Røkenes & Krumsvik, 2016, p. 3). In earlier works (Krumsvik, 2008; 2011), the different terms at use in the field have been discussed. While skills, literacy, and competence are common in the international literature, the introduction of Bildung (Norwegian: dannelse) is a more distinct Norwegian or Nordic approach. The term has been important in Norwegian education and pedagogy generally, as well as being more specifically related to digital competence. Facing recent policy developments indicating a reduced emphasis, Krumsvik (2011, p. 49) argues for a continued and renewed central position for the concept. Digital Bildung includes aspects such as ethics, technology's effects on humans, and a general awareness of the various dilemmas and challenges in a digitised society. Hence, the model not only encompasses basic digital skills and im-

portant factors related to the educational setting but is also, through the Bildung term, attempting to capture a much broader perspective.

Other articles from the period are not as explicit in defining and applying PDC theoretically, but nevertheless raise discussions considering the even broader understandings of technology and education that are vital to the conceptualisation of digital competence (see Brox, 2017; Langseth & Haugsbakken, 2016).

The conceptual article *What Does Professional Digital Competence Mean in Teacher Education?* (Lund et al., 2014) was also published during these years but was not included in this review due to the empirical criterion. Nonetheless, it appears to be a milestone in the concept development and is frequently mentioned, used, and elaborated on in articles in the present review. It is referred to in as many as twelve out of twenty-two reviewed articles, and since 2017, this reference appears in all but one of the reviewed articles. However, this alone says nothing about how and the extent to which its content and thoughts on the subject are applied. In the article, the authors argue for a broader concept of PDC and a deeper understanding of digitalisation's implications for education. They touch on both societal and epistemic consequences and discuss how teachers and teacher education should respond to these issues. Theoretically, like Krumsvik, their approach draws on sociocultural perspectives. A central point seems to be concretising the overall digital competence into a subject-specific understanding, i.e., identifying what challenges and possibilities new technologies bring into each school subject. Hence, they leave room for a specific and concrete exemplification of what this may look like in three subjects. The article's contribution is thus both in painting a broad picture and showing what this means in practice. In the conclusion of the article, the authors refute the notion that their intention has been to suggest a definition (Lund et al., 2014, p. 295). It is perhaps then not so surprising that the articles drawing most clearly on this article's 'definition' of PDC provide quite different citations or recapitulations (see Helleve et al., 2020, p. 327; Instefjord & Munthe, 2017, p. 37; Lund & Vestøl, 2020, p. 5; Thorvaldsen & Madsen, 2020, p. 5285).

Professional Digital Competence for Teachers, 2017–2021

The articles published since 2017 display a greater awareness of the broader questions at hand. Writers seem more likely to apply clear definitions, and there is a more mature understanding of the concept. Discussions of how teachers should deal with ICT, technology, and digitalisation seem to have led to a consensus around and an increased use of the term *professional digital competence* (PDC) as a distinct concept. While international frameworks continue to be mentioned, there is a growing impact on the part of work originating in a Norwegian context. This may be an indication that the conceptual discussions and work in the field in the preceding years has had effect.

However, the work continues, though more gradually, and the articles reflect several scholars' different attempts to define or refine existing definitions of the concept of professional digital competence for teachers. Gudmundsdottir and Hatlevik (2018, p. 217) present and use a three-pillar model of PDC that is inspired by the TPACK model (Koehler & Mishra, 2009) and accredited to Gudmundsdottir and Ottestad (2016). The three dimensions the model is made up of are *generic digital competence*,

subject/didactic digital competence, and *profession-oriented competence* (for details, see **Table 3**). The authors state that the latter is what distinguishes the model from TPACK. Interestingly, the three-pillar model actually appears earlier, in the article *Professional Digital Competence in Teacher Education* (Ottestad et al., 2014). The article was not included in this review, due to its scientific status and lack of empirical material. The authors describe how it was *The Norwegian Centre for ICT in Education* that proposed the model and invited to scholarly debate and academic exploration (pp. 248-249). Hence, the model seems to originate from a joint effort initiated by the ICT-centre to develop and adapt the concept of digital competence to the teacher profession and teacher education. This illustrates how such concept development often is a result of the interplay between policy makers and scholars.

The three dimensions, though not equal, seem to correspond, to a large degree, with the first three components of Krumsvik's model. However, as compared to the way in which the Bildung dimension that overarches Krumsvik's model broadens the perspective, these three dimensions appear to be narrower. An attempt to broaden the concept is made by Brevik et al. (2019, p. 4), who build on the three-pillar model mentioned above by adding a fourth dimension named *Transformative digital agency*. This extended version of the model is found in three additional articles. In Gudmundsdottir et al. (2020) the model is combined with one other model to investigate various aspects of the responsible use of ICT, Lund and Vestøl (2020) narrow down to the fourth dimension in a more theoretical investigation of its analytical usefulness, while Carson et al. (2021) apply the fourth dimension in analysing a specific digital practice.

Some years later, the ICT-centre is once again contributing in this area through publishing a framework for teachers' professional digital competence in which the intention with the concept is said to 'indicate the complexity and breadth of knowledge, skills, and competencies in teachers' professional practice that are associated with understanding the opportunities and challenges in today's digital society' (Kelentrić et al., 2017, p. 2). Dividing PDC into seven competence areas, each with its own description and list of bullet points on knowledge, skills, and competence, certainly paints a broad picture of the concept. However, with no clear definition of PDC provided, the question remains whether this broad perspective simultaneously renders the concept unmanageable to apply in teaching practice or research. It is especially the framework's use of the term Bildung that corresponds with a wider perspective on PDC. This term has played a role in school policy in Norway, both historically and in the current curriculum and, as mentioned above, it is also part of Krumsvik's model. The concept has been the subject of scholarly debate, as has its application to the digital arena. Some find it useful in limited areas, e.g., in relation to ethical issues or critical thinking, but it could also be argued that this concept is well suited to comprehend the broader dimensions of digital competence. At least this seems to be what Krumsvik is attempting by making this term the overarching dimension of his model. Kelentrić et al. (2017) use the term both in general terms and in connection to the specific dimensions of 'School in Society' and 'Ethics'. In the glossary attached to the framework, they provide a definition for digital Bildung that implies a very broad function similar to that of Krumsvik:

> Digital bildung is a term closely related to the German notion of Bildung and tradition of self -cultivation, and as such is often used as an English translation for the Nordic concept of digital dannelse. Digital bildung refers to the integrated development of the individual as a whole person, maturing in a digital culture. It therefore entails actively developing a person's social, cultural, and practical competence in interaction with the digital environment, and being able to link their own digital experiences to the world around them. It also entails a personal maturity, that enables each individual to act in line with social expectations and ethical norms in a digital culture, as well as to reflect critically, and make well-considered and independent decisions. (The Norwegian Centre for ICT in Education cited in Kelentrić et al., 2017)

Surprisingly, to judge by the low numbers of citations in this selection of articles, the framework does not seem to have had much impact in the research field of teacher education. It is only cited in two of the articles. Brevik et al. (2019) mention the framework as an example of the fact that '… PDC is now a well-known concept in Norway' (p. 2). However, as shown above, other definitions and frameworks are actually used in the article. The framework is also brought in by Helleve et al. (2020). They interestingly state that it does *not* define the concept (p. 327) and still later refer to a definition comprised of the design of learning processes, evaluation, and technology selection (p. 333). Though seemingly contradictory, the authors have chosen to focus on some of the many bullet points. Due to the comprehensiveness of the framework, such a selective approach may be the most fruitful way to put it to use and, hence, an understandable solution.

Another suggested model for PDC, the PEAT model, is presented briefly in Gudmundsdottir et al. (2020, p. 3). The model is developed within a European project (Dicte, 2019) to which Norwegian scholars contributed. Similar to the three (four) pillar model, this model is also comprised of four dimensions, though these are different: *pedagogical*, *ethical*, *attitudinal*, and *technical*. The most striking difference is the emphasis on ethics and attitudes, and these are also the dimensions the study focuses on. In the article, the authors argue for a view that the issues of responsible use are transversal skills across all dimensions of the three (four) pillar model. However, this appears as attempting to 'save' the model, which actually seems to lack some dimensions that both the PEAT model and the Krumsvik model have.

Thorvaldsen and Madsen (2020) do not propose some definition or model but, rather, refer to the definitions of Tømte and Olsen (2013) and Lund et al. (2014), and from these, they derive 'three defined aspects of PDC: pedagogic and didactic understanding, subject-specific understanding, and technological understanding" (p. 5285).

A concept outgrowing the field?
The various definitions, frameworks, and models presented in the articles have many similarities. They all stress the importance of exceeding a narrow understanding of digital competence as generic or basic skills. There also seems to be agreement on the fact that the move from isolated skills in using digital tools toward an emphasis on the pedagogical use of ICT for teaching and learning was an important development.

However, this is where differing views become more visible. Where some scholars seem to see this as enough, others argue that this is also too narrow a view. Hence, there is variety in the arguments regarding and descriptions of what should constitute such a broader understanding. As shown above, the term Bildung is one approach that both Krumsvik and *The Norwegian Centre for ICT in Education* have proposed. The term entails aspects of ethics, attitudes, communication, creation, and production and is rooted in a larger perspective on students becoming part of a digital culture (Kelentrić et al., 2017).

Another argument for the broader perspective is found in the need for a deep technological understanding. This is foundational in the work of Lund et al. (2014) but also an important part of several discussions in other articles (e.g., Brevik et al., 2019; Brox, 2017; Langseth & Haugsbakken, 2016). Despite not always containing an explicit link to common notions of digital competence, these articles still bring up important discussions about the implications of digitalisation for education and the challenges the field faces when attempting to relate to constantly evolving technologies. The limitations to this deeper understanding caused by the commonly used tool metaphor have been pointed out by several authors. 'Technologies that do not act according to plan, provide resistance or fail to deliver improved learning outcomes will be dismissed in favour of well-trodden paths and reproduction of existing practices' (Brox, 2017, p. 139). The work on digital agency by several scholars (see Brevik et al., 2019; Carson et al., 2021) is also aware of such challenges. Lund and Vestøl (2020, p. 1) write that 'Digitalization does not merely result in powerful tools at our service but materializes in objects with intentions that interfere with and even override human decisions.'

The speed of technological development is also obviously an important part of the challenge of defining digital competence. What seemed, at the moment, to be an important tool or practice may not be shortly thereafter. The need to develop a concept that emphasises more general dimensions, without becoming entirely theoretical, is therefore evident. One article put it as this in a concluding remark:

> By the time they enter the classroom as teachers, tools may already be outdated. Focus should therefore be directed away from mastery of tools themselves and towards appropriation of a digital competence that embraces awareness of how technology can be used critically and reflectively in the process of building new knowledge. (Instefjord, 2014, p. 328)

This speed may also lead to a problematisation of the ideal of research-based and theory-informed teaching practices, as Langseth and Haugsbakken (2016, p. 62) write that 'research says much about what has promoted formal learning, less about what promotes learning in today's and tomorrow's technology informed educational cultures.'

Following the chronological development outlined above, one can see that broader perspectives are becoming more common in the field, both in explicit concept development and through discussions. Despite this, the tool metaphor persists in terms of both language and research focus. This is evident in both quantitative (questions asked) and qualitative studies (descriptions, case selection). One example of this ap-

parent discrepancy appears when Røkenes and Krumsvik (2014) both communicate a broad understanding of digital competence and related concepts and, simultaneously, leave it unclear whether PDC is understood as equal to ICT for learning. Phrases such as the 'use of ICT' and the 'use of technology in teaching' appear frequently in the review. This may be due to the historical nature of a literature review, and the fact that much of the reviewed research has been inclined toward such an understanding. However, we see the same tendency in other, newer studies as well. Instefjord (2014) maintains a broad understanding of digital competence in the introduction but chooses to focus on 'the development of digital competence as a tool for teaching and learning' (p. 315), and even recent studies employ similar 'tool-language' (e.g., Bader et al., 2021; Thorvaldsen & Madsen, 2020).

One possible explanation for this discrepancy can be found in the impact of sociocultural perspectives, in which the use of tools or artifacts has been essential in understanding learning (Helgevold & Moen, 2015, p. 40). As shown above, this theoretical tradition has informed and influenced the field of digital competence in the Norwegian setting. Another explanation could be that the theoretical concept development precedes the empirical research. If so, what we observe is a field still in the process of adapting both teaching and research practices to the broader concept understanding. A different approach, however, could be to question the problematisation of the narrowness of tool language. Perhaps broader perspectives, in more general terms, serve best as underlying and legitimising the use of ICT in schools, while the most useful focus in school practice and school development is focusing on questions regarding how to use ICT, as a tool, in good pedagogical and didactical ways. Nonetheless, the words and metaphors we use are important; hence, one should be aware of the risks discussed here.

5   Conclusion

The extent to which the studies define the term 'digital competence' varies, but some trends regarding how the term has developed over the years are evident. This development tends toward more concise definitions of digital competence and a more solid theoretical foundation. The earliest articles in the selection mention digital competence, with few if any references to theoretical frameworks, while more recent studies draw upon extensive concept development, both international and, increasingly, national. Based on the earliest findings in the review search, the 2009 to 2015 period, the research is, to a great degree, tool oriented. The focus is on testing and researching different applied tools and discussing didactics related to the experience gained through this.

From 2014 to 2017, a greater awareness of the professional complexity of digital competence in education emerges. The discussions, to a greater degree, concern the transformation of education due to digital technology, not how digital technology can supplement, improve, and enhance traditional teaching. In 2017, the term 'digital competence' is explicitly context-defined for teachers, as professional digital competence is introduced through the *Professional Digital Competence Framework for*

Teachers. This framework defined an extensive and complex understanding of teachers' professional digital competence. The TPACK-framework (Koehler & Mishra, 2009) appears to represent a recurrent framework when Norwegian researchers are conceptualising and defining digital technology, even though theory development by Norwegian researchers seems to increasingly take the place for this and other international frameworks. In different ways, they aim for concepts and definitions that are broad and include the multitude of challenges and possibilities created by digital technology development.

However, there are several dilemmas arising from this. One is that the broad understanding of PDC makes measurement a difficult task, which is shown in the review of methods. There also seems to be a challenge in establishing a coherence between theoretical foundations and actual research. Claiming that digital competence is more than tool use but then going ahead and investigating exactly this is clearly incoherent. Hence, finding ways to both develop and, if possible, measure aspects of PDC that reflect broader perspectives is required. Regarding measuring of digital competence, this review also points out the frequent use of self-reporting. Further research may benefit from combining this with other approaches that measure and test actual practices or skills.

While digital competence, as an important aspect of teachers' professional competence, has gained attention in both empirical research and conceptual development, this review reveals that an important subgroup, pre-school teacher students, seems to be less prioritised. Further research should investigate PDC in this area in terms of policy, practice, and concept development. Research concerning some more recent developments in technology and education was surprisingly absent in the articles. The establishing of Future Classroom Labs in several Norwegian teacher education institutions would have been a relevant research area regarding teachers' PDC. Computer gaming and VR (virtual reality), two technologies gaining increased attention in schools, are not mentioned either. These are all areas that further research concerning pre-service teachers' digital competence should investigate.

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