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Developing professional digital competence in Norwegian teacher education: a scoping review

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The widespread use of educational technology in schools compels teachers to seamlessly integrate technology while developing students' digital competence. As educational technology continually evolves, digital competence becomes a dynamic target. Thus, teacher education must effectively prepare student teachers to teach effectively with technology. Researchers are increasingly examining the concept of teachers' digital competence and how teacher education supports student teachers' acquisition of digital skills for future employability. In Nordic countries like Norway, the term Professional Digital Competence (PDC) frames a teacher's essential knowledge for using digital technology in teaching and learning. Despite this focus, there's limited understanding of how Norwegian teacher education fosters PDC. This scoping review investigates current research on PDC and its implementation within Norwegian teacher education. Findings from numerical and thematic analysis offer insights into the prevalent types of PDC research. Thirty-four peer-reviewed papers were identified and coded along three dimensions: (1) theoretical perspectives, (2) research questions and methods, and (3) application and implementation. The review reveals a predominant focus on student and teacher educator perceptions or self-assessments when measuring digital competence. Our findings show that professional digital competence in teacher education is diverse and multifaceted. However, there are gaps in the current state of knowledge. To address this, we propose a definition and a framework to guide teacher educators. Future research should broaden participant profiles and involve a more diverse group of educators.

KEYWORDS

professional digital competence, teacher education, dual didactic role, PDC definition, teacher educators, student teachers, scoping review

1 Introduction

1.1 Digital competence in teacher education: a dynamic challenge

The rapid advancement and widespread incorporation of educational technology in classroom settings pose significant challenges for educators in effectively integrating such technology and cultivating the digital competence of their students. In the dynamic and

ever-progressing domain of educational technology, the concept of digital competence is continually evolving. This shifting paradigm necessitates that teacher education programs remain up-to-date and consistently equip student teachers with the necessary skills to effectively utilize technology in their teaching practices (Krumsvik, 2011, 2012).

1.2 Professional digital competence in a nordic perspective

In the Nordic context, particularly in Norway, Professional Digital Competence (PDC) has emerged as a defining concept specifying the essential knowledge and skills a teacher must possess. This growing emphasis on dissecting and comprehending what teachers' digital competence is, includes a thorough exploration of how teacher education programs can enhance student teachers' digital skillsets and ensure that these competencies align with the demands of the modern workforce.

Despite its recognized importance (Starkey, 2020; Starkey and Yates, 2020; Skantz-Åberg et al., 2022), there is a noticeable gap in comprehensive research regarding the development of PDC within the context of Norwegian teacher education. To bridge this knowledge gap, this scoping review delves into existing research on PDC with a specific lens on its incorporation and manifestation in Norwegian teacher education. The review aims to map out the current landscape, uncover the extent of PDC's integration, and identify potential avenues for future research and development in this critical area of teacher professionalization.

1.3 Background and need for PDC in teacher education

1.3.1 Teacher education and technology integration

Historically, teacher education programs globally have aimed to reflect the realities of the teaching profession. As such, there has been an emphasis on the integration of information and communication technology (ICT) in teacher training curriculum to bridge the disconnect between real-world classroom settings and the academic realm of teacher education. However, is this presumption backed by the current state of knowledge or is it merely a result of political enthusiasm for innovation in teacher education? Is this another instance of a technology frenzy, or is it a necessary evolution in our increasingly digitized schools? And what kind of digital competence frameworks seems to be relevant in such processes? These issues merit discussion, serving as a starting point for this paper. After all, we are still navigating the early stages of a full-scale integration of digital technology in teacher education, and this uncharted educational territory often raises more questions than it answers. This is largely because it is a relatively recent development in teacher education, and there is not an abundance of longitudinal studies to reference (Krumsvik, 2011, 2012; Tondeur et al., 2012; Røkenes and Krumsvik, 2014); thus, more knowledge and research are needed to formulate robust, research-based knowledge bases. This has also become more relevant as the global Covid-19 pandemic made schools and higher education institutions all over the world switch from physical to blended and online learning (Bonk and Graham, 2005), and to implement a pedagogy of emergency remote teaching and online emergency education (Hodges et al., 2020; Damşa et al., 2021). In Nordic countries such as Norway, the so-called "Great Online Transition" (Sang et al., 2023) compelled teachers, teacher educators, and many other professions to disclose their digital competence as they were switching to online and hybrid forms of teaching (Krumsvik, 2020). A study on teachers in Norway and the United States during the pandemic showed that they were "inexperienced and unprepared" to teach online, but "moderately confident with using digital tools" (Gudmundsdottir and Hathaway, 2020). What worried the researchers though, where how few teachers were concerned with ethical issues.

1.3.2 Ongoing discussions and project initiatives

Meanwhile, at the time of writing, generative artificial intelligence (AI) tools based on natural language processing large language models, such as the virtual chatbot ChatGPT, has caused heated debates across the entire education sector about assessment, academic integrity, and future employment since its release in November 2022 (Bozkurt, 2023; Krumsvik, 2023). In a such time of upheaval teachers, teacher student and teacher educators need to have a spectrum of digital skills, knowledge, and attitudes. Not only for times of crisis, but in everyday life as in teacher education. For almost 25 years, Norwegian researchers, teacher educators, teacher students, teachers and policymakers have discussed what kind of digital competence a teacher needs in an increasingly digitized school. An important part of the state of knowledge has been four significant digitalization endeavors: PILOT, PLUTO, DigGLU, and GrunnDIG. The PILOT project (Krumsvik, 2006) along with Learning Networks (Ottestad et al., 2010) stand out as the most extensive and broad innovation projects linked to the pedagogical employment of ICT in schools to date. These projects, spanning 4 years, encompassed 120 schools, three universities, and four university colleges (Erstad, 2004; Krumsvik, 2006; Erstad and Hauge, 2011). Krumsvik, 2006 doctoral thesis, an outcome of the PILOT project, explored ICT-initiated school advancement in Norwegian secondary schools, thus pioneering a new perspective on teachers' digital competence within the frames of the national curriculum as distinct from a broad understanding of digital competence (Erstad et al., 2005; Krumsvik, 2006). Krumsvik's digital competence model also included digital competence for teacher educators (Krumsvik, 2011, 2012) and was subsequently tested among approximately 20,000 Norwegian students and teachers in upper secondary school (Krumsvik et al., 2013, 2016; Moltudal et al., 2019). The PLUTO project (Program for Teacher Education, Technology and Change 2000–2004) engaged seven Norwegian teacher education facilities and schools of varied educational stages (Ludvigsen and Rasmussen, 2006; Hauge, 2015). Numerous research investigations stemmed from PLUTO, but a common tendency where that implementation of ICT in teacher education in Norway where challenging. The third project, DigGLU (Digitalization of Primary and Lower Secondary School Teacher Education 2018–2020), included localized projects across five Norwegian teacher education institutions (Arstorp and Røkenes, 2022). A shared attribute of these sub-projects is the gradual transition from a teacher-oriented approach toward one of student-engaged learning, and the exploration of new pedagogical and didactic methods to enhance student learning with digital technologies. Still, the DigGLU and NOKUT evaluations (NOKUT

2022) show that teacher education struggles with a full-scale implementation of both ICT and digital competence generally.

The GrunnDIG-project (2022–2023) resulted in an extensive report and found that teacher education has plenty of room for improvement when it comes to the implementation of ICT and digital competence (Munthe et al., 2022). The study reveals that it is, e.g., a paradox that teacher educators and teacher students have little access to digital learning materials and resources in their teacher education when they are expected to develop the competence to critically evaluate learning materials and be able to use digital learning materials in their practice as teachers.

On the backdrop of these four projects and discussions in the research communities in Norway around 2013–2015 it has been a consensus over the years that teachers, teacher student and teacher educators need a more specific framework of digital competence in line with the national curriculum, research, and experiences.

1.3.3 PDC development emerging in teacher education

For the past decade, several reviews have examined the topic of PDC development, technology-preparation, and ICT-use in teacher education (Tondeur et al., 2012; Røkenes and Krumsvik, 2014; Uerz et al., 2018; McGarr and McDonagh, 2019; Skantz-Åberg et al., 2022; Tveiterås and Madsen, 2022). However, previous reviews have mainly focused on exploring student teachers' perceptions on using digital technologies in teaching and learning and their levels of digital competence. Paradoxically, teacher educators continue to remain an overlooked and under-researched group of professionals in terms of their beliefs, practices, and levels of PDC, as well as how they address PDC at the institutional level (Nagel, 2021; Smith et al., 2021). Currently, no study has explored the existing research literature specifically on the Norwegian term PDC in Norwegian teacher education, what are teacher educators' perceptions on PDC, and how they operationalize and implement PDC in their subject disciplines with student teachers and other relevant contexts. The Norwegian term PDC and the Norwegian teacher education context are interesting to investigate because the entire education sector has undergone large scale investments by the government in digital technology, including the professional development of teachers and teacher educators, prior to the Covid-19 pandemic (Amdam et al., 2022; Andreasen et al., 2022; Arstorp and Røkenes, 2022; Aagaard et al., 2022; Røkenes et al., 2022). In addition, with the PDC Framework for Teachers (Kelentrić et al., 2017), PDC is implemented in the national regulations for Norwegian teacher education (Ministry of Education, 2016). Furthermore, in Norway as in many other countries, the global pandemic seems to have increased the roll out and uptake of digitalization at all levels of the education system (Krumsvik, 2021). Consequently, the focus on developing teachers' PDC in Norwegian education puts pressure on teacher education to prepare future teachers with the necessary PDC for meeting the teaching requirements in today's digital school and society. The latter includes an awareness of societal opportunities and challenges brought on by the global pandemic and emerging technologies such as using online or hybrid teaching models, reflecting on ethical dilemmas with artificial intelligence tools (e.g., ChatGPT) in students' assignments, and addressing concerns with online source credibility. To address the knowledge gap in the research literature, we conducted a scoping review with the purpose of uncovering how teacher educators perceive, develop, operationalize, and implement PDC in teacher education.

1.4 Scope and research questions

The focus of the review is to look at the concept professional digital competence (PDC), explore how the concept is addressed in Norwegian teacher education (TE), map in what ways previous research discuss teacher educators' PDC and to look at what focus is on transferring existing competencies to new technologies. To ensure that we got a broad picture of our theme within the range of literature, we posed the following research questions to guide our review:

> *RQ1:* What is known from the current state of knowledge on the implementation of professional digital competence (PDC) in Norwegian teacher education?
>
> *RQ2:* In what way is previous research informing teacher educators on the operationalization and implementation of professional digital competence (PDC) in Norwegian teacher education?
>
> *RQ3:* What focus does the current state of knowledge have on support for transferring existing competencies to new technologies and situations?

The rest of the paper is structured as follows: The first section gives a historical overview of the concept PDC and the PDC Framework for Teachers. The methodology section outlines the research design and scoping review process. The final sections present and discuss the results of the review, and end with a conclusion that includes study implications, limitations, and recommendations for further research.

1.5 What is professional digital competence

1.5.1 Historical overview of PDC in Norwegian context

Building upon his earlier research (Krumsvik, 2006), Krumsvik proposed a definition of teachers' digital competence in 2007 (Krumsvik, 2007, 2008, 2009) and in 2011, he also included teacher education: "Digital competence is the teacher/TEs' [teacher educators'] 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, 2011, p. 44–45). In 2012, he refined his definition to specifically address teacher educators' digital competence. He emphasized its integration as a natural part of their profession and professional development, outlining four key dimensions: *basic ICT skills, didactic ICT competence, learning strategies, and digital bildung* (Krumsvik, 2012, p. 6).

And building on the abovementioned previous models, policy documents and research, the Norwegian Center for ICT in Education coined the concept PDC in 2012. And in 2013, The Norwegian Center for ICT in Education and Tømte et al. (2013) published a report, titled

ICT in teacher education: Toward Professional Digital Competence? (our translation) were an important contribution and a following positioning paper (Tømte et al., 2013), opened up a discussion on the need to elaborate on how teachers can use ICT didactically in teaching and assessment. In 2014, the *Nordic Journal of Digital Literacy* had special issue on digital competence in teacher education where in his editorial, Søby (2014) called for a more systematic approach on the preparation of student teacher to learn how use of digital technology in teacher education programs: "While formal requirements for the use of ICT are mandated within the national curriculum for students, similar expectations for teacher training programs are missing at both the national and institutional level" (Søby, 2014, p. 241). The special issue further introduced research from Norwegian teacher education and highlighted many initiatives and teacher educators who teach with, on, and through technology. Also emerging from the special issue was a growing understanding of what PDC entailed. Ottestad et al. (2014) proposed three dimensions to describe teachers' PDC: *generic digital competence*, *didactic digital competence,* and *professional oriented digital competence*. Lund et al. (2014) focused on dimensions that help conceptualize PDC as "the relationship between digital technologies and learning; how such technologies also bring about performative competence in education; and how structural aspects of classroom management needs to be addressed in teacher education" (Lund et al., 2014, p. 286). Johannesen et al. (2014) theoretical paper suggested three aspects for PDC: "teaching of ICT; teaching about ICT; as well as teaching with ICT" (Johannesen et al., 2014, p. 308). Røkenes and Krumsvik's (2014) literature review advocated using different approaches for ICT-training to promote PDC in teacher education. Finally, Instefjord (2014) points out that teachers' digital competence needs to move "away from proficiency in tools […] toward 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).

1.5.2 The role and characteristics of PDC in education

From this we can see that in an educational context, teachers, teacher educators, and pre-service teachers are expected to use digital technology in a pedagogical way that promote subject disciplinary learning, and the development of digital competence/literacy and other types of skills. The latter is arguably linked to terms such as 21st Century Skills which involve developing a wide range of core skills in collaboration, leadership, creativity, critical thinking, and problem-solving (Erstad and Voogt, 2018). Similarly, the former is related to the knowledge, skills, creativity, and attitudes required to use digital media critically and confidently for work, learning, comprehension, communication, and leisure in today's technology-saturated society (European Commission, 2007; Krumsvik, 2011, 2012).

The term teacher professional digital competence (PDC) narrows the focus from a societal level, including citizens and students' use of digital technology, to that of the teaching profession (Røkenes and Krumsvik, 2016; Kelentrić et al., 2017). As opposed to other users, teachers' use of digital technology differs because they need to consider how such technologies can support the design of teaching and learning activities as well as pedagogical and didactical aspect including what to use, why, how, when, and where (Lund and Hauge, 2011; Røkenes and Krumsvik, 2016). In other words, PDC means moving away from perceiving digital competence as "a set of generic skills suitable for all situations, both personal and professional, and toward an understanding of PDC that includes both generic *and* specific teaching profession skills" (Lund et al., 2014, p. 283, italics in original). Lund et al. (2014) argue that in teacher education "PDC involves teachers not only appropriating technologies, but also making their learners appropriate them and put them to productive use" (Lund et al., 2014, pp. 283–284). They further underscore that "technologies are understood, applied, and made relevant differently in each school subject in which they are integrated" (Lund et al., 2014, p. 284), which relates to the didactics of each subject matter. In teacher education, Lund et al. (2014) emphasize that student teachers develop PDC by "uniting a view of technology, dimensions of learning theory, and educational science into a subject-specific context" (Lund et al., 2014, p. 284), so that they can operationalize and express PDC in pedagogical practices in the school. Consequently, this puts pressure on teachers and teacher educators professional learning to possess PDC as they are important digital role models for students and student teachers' use of digital technology in the various subject disciplines (Røkenes and Krumsvik, 2016; Røkenes et al., 2022).

1.5.3 The Norwegian framework

In, 2016, a requirement for student teachers to possess 'profesjonsfaglig digital kompetanse' (professional digital competence) was explicitly incorporated into the National regulations for teacher education (Ministry of Education, 2016, p. 1). In 2017, the Norwegian Directorate for Education and Training (by then merged with the Norwegian Center for ICT in Education) released the Professional Digital Competence Framework for Teachers. The intention behind introducing the term PDC was to give "substance and meaning to the concept of teachers' professional digital competence, and thereby establish a basis for competence development and improve the quality of this in the teaching profession" (Kelentrić et al., 2017, p. 2). Further on, the framework attempted to illustrate 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). In this regard, the framework puts forward a common conceptual apparatus and frame of reference on what PDC implies for educators. The Norwegian framework was developed based on Norwegian national regulations for education, as well as international frameworks and evaluation tools for digital competence. As a policy document on competence for the teaching profession, seven domains are presented as a starting point for viewing the teacher's competence from a digital perspective. Within each domain, there are descriptions of knowledge, skills, and competence according to the Norwegian National Qualifications Framework.

1. *Subjects and basic skills*: Teachers enhance subject and basic skills through digital tools, intertwining digital literacy with reading, writing, numeracy, and oral skills. They continuously develop both their own and their pupils' digital abilities, aligning educational goals with digital fluency.
2. *School in society*: Digitally competent teachers grasp digital media's societal impact, bridging the digital divide and fostering ´digital bildung`. They prepare students for the digital future, emphasizing creativity, critical engagement, and digital participation.

3. *Ethics*: Educators navigate digital ethics, cultivating democratic values and responsible online behavior. They address legal and ethical concerns, focusing on digital citizenship, privacy, and intellectual property.
4. *Pedagogy and subject didactics*: Teachers integrate digital resources with pedagogical and subject knowledge, customizing learning to fit different needs. They employ a range of digital tools and materials, fostering reflective, engaging teaching practices.
5. *Leadership of learning processes*: Teachers guide adaptive, inclusive environments using digital tools, tailoring education to individual student needs. They employ varied assessment and feedback as well as adapting their teaching roles to enhance digital learning.
6. *Interaction and communication*: Teachers use digital platforms for collaboration, enhancing communication and community. They promote positive interaction and professional growth, leveraging digital tools for educational improvement,
7. *Change and development*: Educators view digital competence development as ongoing, informed by research and practice. They update curricula and teaching methods based on digital advancements, contributing to the educational community's evolution.

1.5.4 Defining PDC

Based on the PDC-framework, our previous studies on teachers and student teachers' digital competence (Krumsvik, 2007, 2008, 2009; Røkenes and Krumsvik, 2014, 2016) and previous definitions of teachers and teacher educators' digital competence (Krumsvik, 2011, 2012), we propose the following definition of PDC:

Professional Digital Competence is the comprehensive ability for teachers to effectively and responsibly use digital technologies in education, including integrating them into subject-specific teaching, designing educational activities, making informed decisions about tool use, guiding students in productive digital use, and considering societal and ethical implications of technology. This definition remains dynamic, continuously shaped by the current state of knowledge, theoretical approaches, and experiences from the practice field.

1.5.5 Previous research

Internationally, we observe that researchers and policymakers seem to be moving away from the more general concept of digital competence, and instead use other terms similar to the Norwegian concept teacher PDC such as the European Commission's European Framework for the Digital Competence of Educators (Redecker and Punie, 2017), or UNESCO's ICT Competency Framework for Teachers (UNESCO, 2011). Perhaps one of the most used constructs on technology integration in teacher education, is the Technological Pedagogical Content Knowledge (TPACK) framework (Nelson et al., 2019). Research from the United States using Mishra and Koehler's (2006) TPACK underscore that successful integration of technology in teaching and learning must consider the intersection of pedagogical knowledge, content knowledge, and technology knowledge. Other studies use the term ICT competence or Teacher Digital Competence (TDC) when referring to what is require of a teacher educator when using digital technology for teaching and learning (Kotzebue et al., 2021; Smith et al., 2021; Sang et al., 2023). Another framework deriving from the United States, the Teacher Educator Technology Competencies (TETCs) provide teacher educators with a set of technology guidelines (Carpenter et al., 2020), including 12 competencies envisioned as the expertise that "all teacher educators need in order to support teacher candidates as they prepare to become technology-using teachers" (Foulger et al., 2017, p. 413).

Since 2017, when the Norwegian PDC-framework was launched, Norwegian TE has had a common conceptual apparatus and frame of reference on what PDC entails. PDC has been an integrated part of the Norwegian national regulations for teacher education, and from 2013 onwards, a body of research from Norway has focused on the term PDC or nearly synonymous concepts (e.g., Krumsvik, 2011, 2012; Tømte, 2013; Instefjord, 2014; Røkenes and Krumsvik, 2014). In the wake of the launch of the PDC-framework, there has also been a growing interest for the implementation of PDC in Norwegian TE. At the present, however, no overview of this research is available. Therefore, the main objective of the current review is to systematically identify, critically analyze, report, and discuss the scientific research on PDC in Norwegian TE. Seeing as few studies have applied the concept teacher's PDC with teacher educators in Norway, we undertook a scoping review of the literature on PDC in Norwegian teacher education. In this study, we use the term competence rather than literacy because in a Scandinavian context, the term literacy (i.e., reading and writing) "does not translate to the languages in these countries" (Erstad, 2010a,b, p. 57). Moreover, we focus specifically on the concept PDC rather than the general concept of digital competence or other similar concepts (e.g., information competence, media competence, 21st Century skills). The reason for this is two-fold: (1) to narrow the scope of the review, and (2) to explore how the PDC concept has been operationalized and implemented in research on teacher educators.

2 Methodology

The research design for the current literature review study is scoping review (Arksey and O'Malley, 2005; Levac et al., 2010; Colquhoun et al., 2014). A scoping review is a type of evidence synthesis that can, with the use of systematic and explicit methods (Munn et al., 2022), assess the "potential size and scope of available research literature" (Grant and Booth, 2009, p. 101). Scoping reviews are a useful approach to "map evidence on a topic and identify main concepts, theories, sources, and knowledge gaps" (Tricco et al., 2018). Moreover, scoping reviews share several traits with systematic reviews in attempting to be "systematic, transparent, and replicable" (Grant and Booth, 2009, p. 101).

The present study applied Arksey and O'Malley's (2005) six-stage framework for scoping reviews. Step 1 involves identifying the research question(s), purpose, and scope of the review. In steps 2–4, database searches were conducted where relevant studies were identified, selected, and charted for data. Finally, in step 5, the data were collated, summarized, and reported in the results section. Step 6 is an optional consultation exercise with stakeholders and was not included in the study. The following sections in the methodology are structured and labeled according to the five stages outlined in Arksey and O'Malley's (2005) framework for scoping reviews. The first step, "identifying the research questions," has been presented in the introduction section of the paper, and the rest of the methodology section presents steps 2–5.

2.1 Identifying relevant studies

The second step in the scoping review was to identify relevant studies through mapping our core concepts and combining these into a search string for use in the database searches. To cover a broad range of studies regarding teacher PDC, the search term *"professional digital competence"* was selected. The reason for selecting the search term without applying any other filtering options was to cover as broad a range as possible in the database searches.

Balancing the desire for breadth with the timeframe and resources of the project, six educational and social science research databases were used to conduct the search in the scoping review: ERIC (EBSCO), Web of Science, ProQuest, Science Direct, NORART, and Idunn. In the Nordic databases NORART and Idunn, we also performed an additional search for the Norwegian term for PDC: *"profesjonsfaglig digital kompetanse* "to include potential research reported in the Norwegian language only, as the term "professional digital competence" originates from a Norwegian educational policy discourse. This yielded four articles, with one of them already compassed in the English search (in the same databases).

The database searches resulted in a total of 730 studies, and were limited to peer reviewed publications in English, Norwegian, Swedish, or Danish. Even though we were only interested in publications from a Norwegian research context, we also included English, Swedish, and Danish languages too in case researchers from these countries had conducted studies on Norway teacher education and published in these languages. Because the PDC-framework was published in 2017, the time span was set from January 1, 2017, to December 31, 2022. The initial search was undertaken on March 23, 2023, and yielded 8 articles in ERIC (EBSCO), 43 in Web of Science, 597 in Scopus, 26 in Science Direct, 17 in Education Source (EBSCO), 38 in Idunn (search in Norwegian and English), and one in NORART (search in Norwegian).

2.1.1 Inclusion/exclusion criteria

The identification of relevant studies started with developing a set of inclusion and exclusion criteria to narrow the scope of the review, and all studies were assessed against the criteria listed in Table 1. The process involved manually applying exclusion criteria by screening studies based on titles and abstracts. Included were peer-reviewed journal articles that reported research on PDC in teacher education, and that were published between 2017 and 2023. Excluded were non-peer reviewed articles and articles that examined other contexts such as the primary and secondary schools, adult education, and other disciplines within higher education such as nursing, political science, business, and so forth. Gray literature including conference proceedings, book chapters, books and book chapters, reports, policy documents and more were also excluded. Articles published before 2017 or after 2022 were excluded.

2.1.2 Screening

The titles and abstracts of the 730 articles were screened to assess their relevance. The manual identification process was completed in two parts. First all articles were imported into the reference software EndNote 21 where 10 duplicate articles were removed. Next, titles and abstracts of the 720 remaining articles were exported from EndNote and imported in a spreadsheet. The process started with a preliminary scan of titles and abstracts. Articles that did not address PDC in teacher education were excluded. Based on this preliminary screening 584 of the articles did not meet the criteria.

In the next phase a screening of the remaining 136 articles, 67 articles were rated as not relevant. Most of the excluded articles focused on technology-use in schools (primary and secondary), not teacher education. Moreover, many of the excluded articles originated from higher education, the health sciences, and public sector, with some from other disciplines subjects like computer science, engineering, and architecture.

Thirteen articles were difficult to assess based solely on the abstract. These articles were further scanned full text for a more thorough assessment. From the full text scanning of these 13 titles, 3 were found to cover the inclusion criteria.

The final phase, a full-text reading of the articles was necessary. Only articles that addressed primary studies from TE were included.

This screening revealed articles that were not primary studies, like review studies, or another type of education studies, like language learning. A few were also written in a language not excluded from the search, even with the criteria after, like Spanish.

TABLE 1 Inclusion and exclusion criteria.

	Included	Excluded	
Databases	Eric (EBSCO), Web of Science, Scopus, Science Direct, Education Source (EBSCO), NORART, Idunn	All other databases (e.g., PubMed, PsychInfo, Google Scholar, Medline)	Exclusion through search
Time frame	2017–2022	Articles published before 2017 or after 2022	
Publication type	Peer-review articles	Non-peer-reviewed articles, unpublished/gray literature (e.g., conference papers, conference proceedings, MA-theses, Ph.D.-dissertations, reports, anthologies, books, book chapters, news articles, essays, editorials)	
Language	English, Norwegian, Swedish, Danish	All other languages	
Topic/focus	Empirical studies with primary focus on (1) professional digital competence (concept) and (2) teacher education (context)	Articles focusing on other concepts (e.g., general digital competence, digital literacy, media literacy, information competence) and research contexts (e.g., primary school, secondary school, adult education)	Manual *screening*

2.2 Study selection

2.2.1 Eligibility

Step 3 involved assessing and selecting studies for inclusion in the review. During the stage of the full-text reading, 25 articles were considered irrelevant and excluded.

An initial challenge in the title and abstract screening was related to two kinds of levels of student teachers and teacher educators, where the abstracts did not always make explicit whether the study is regarding 1st order or 2nd order teachers (Uerz et al., 2018). Another challenge was to find the articles that focused on Professional Digital Competence as concept addressed *in* the article and not only as a bibliographic reference.

Authors 1 and 3 conducted the database search individually and got the same result. All the authors were part of the screening process. Author 1 developed a documentation of the paper trail. This was based on the spreadsheet from the screening process, where every decision was documented using comments, filters and categories. All the authors had access and used this document. In cases where we were unsure the authors discussed every decision pertaining to include or exclude articles. Most of the excluded articles were not discussing PDC in Norwegian teacher education (e.g., teaching with digital technology in health science), were not situated in a Norwegian teacher education context (e.g., Irish teacher education), were outside the scope of the review (e.g., published before 2017 or after 2022), were not peer-reviewed empirical articles (e.g., reports, editorials, book chapters), or were other types of competence not in direct relation to PDC (e.g., digital literacy, computational thinking skills, 21st century skills).

Reporting the results of the database searches was done by drawing on the guidelines outlined in the Preferred Reporting Items for Systematic reviews and Meta-Analyses statement extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). Figure 1 is a flow chart showing the search, inclusion, and exclusion processes, screening and selection carried out for reporting the results of the items in the study.

2.3 Studies included in data extraction and synthesis

A total of 34 research studies met the inclusion criteria for further analysis

3 Result and analysis

3.1 Data charting and collation

The fourth step involved charting the data with creating a summary, collation, and synthesis of each study. Every study was scrutinized, and data was extracted based on indicators that included: author, year of publication, research design, methodology, data source, sample size, study population, the education level of interest in the studies, intervention, theoretical framework, and how the studies informed teacher education. A detailed overview of the included studies can be found in the Supplementary material.

Next, all studies were analyzed using strategies from coding and categorization (Saldaña, 2021). The thematic evolution from codes and categories to the emergent themes were first constructed based on a process of initial or open coding where tags were attached to the text across the studies (e.g., PDC conceptual and theoretical framework references, role of teacher educator, attitudes toward educational technologies etc.). Through a second cycle of coding, patterns of codes and categories that were found to be similar were compared, merged, reorganized, and further developed into substantial meaning-bearing categories (Saldaña, 2021). The main themes evolved from sub-themes related to strategic documents, program plans, cross curricular courses and pedagogical integration; from various ways PDC is conceptualized and defined; from the underlying theoretical models and frameworks that support the operationalization of PDC; and finally from discussions on the didactical implications of both teaching using digital tools to enhance learning as well as developing students digital competence.

3.2 Summarizing and reporting findings

The fifth and final step of the scoping review according to Arksey and O'Malley's (2005) framework was to summarize and report findings considering the distillation that were taken. The summaries that were developed in data charting made reporting of the findings easier to calculate, follow and discuss. The calculations and graphs are made with Python.

In the following we first present the general characteristics of the included studies followed by the methodology characteristics. Ultimately the research foci and emerging themes will be introduced.

3.2.1 General characteristics of included studies

The overall trends of the studies in question is presented in a graphical analysis, delineating key trends and patterns across the publications.

Categorized through distribution year, the subsequent graphs and description show the number of articles, number of cooperation, number of longitude studies, number of citations, and number of interventions presented.

Figure 2 is a visual representation of data concerning the number of articles published over a six-year period since the introduction of the framework PDC. Each bar corresponds to a year, and the height of the bar indicates the number of articles published in that year.

There is an overall increasing trend in the number of articles published from 2017 to 2020, with a particularly notable jump between 2019 and 2020 (2 years after the PDC were implemented in Norway). The year 2020 shows the highest number of publications within the data set, suggesting a peak in article production or reporting that year.

Following 2020 there is a slight decrease in the number of articles published in 2021. This could be indicative of various factors such as natural variations, or other external factors affecting the publication processes of articles. In 2022, there is a slight increase from 2021, yet the numbers have not returned to the peak observed in 2020.

These observations seem to be quite natural since it is only 6 years since the PDC-framework were implemented in the Norwegian educational context. However, if the decline from 2020 continues in

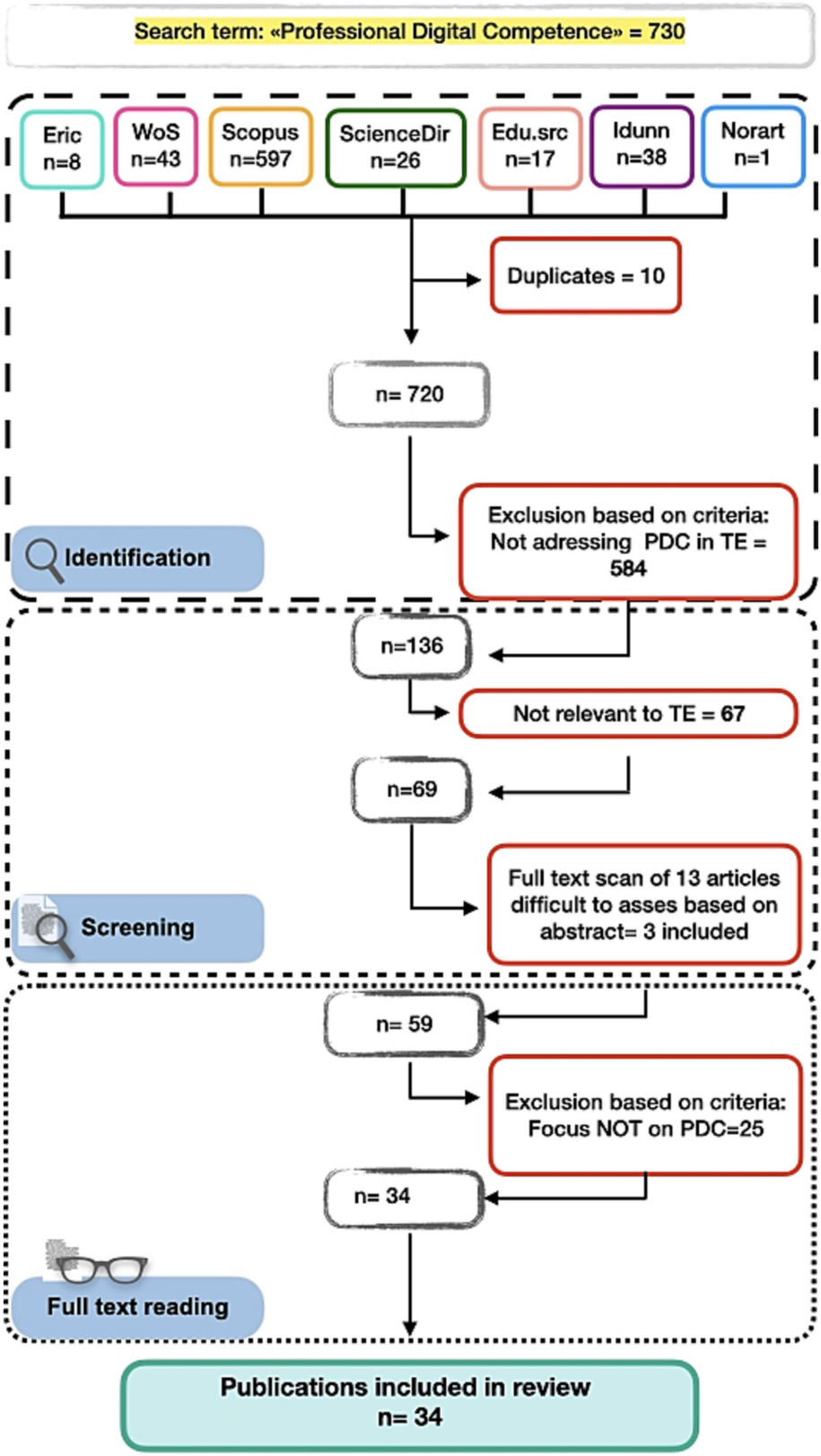

FIGURE 1
Search flow chart based on PRISMA.

the coming years, further investigations to understand the reasons behind the fluctuations are important to follow. Factors to consider could include changes in the research and publication landscape, such as increased research activities in certain fields, the impact of global

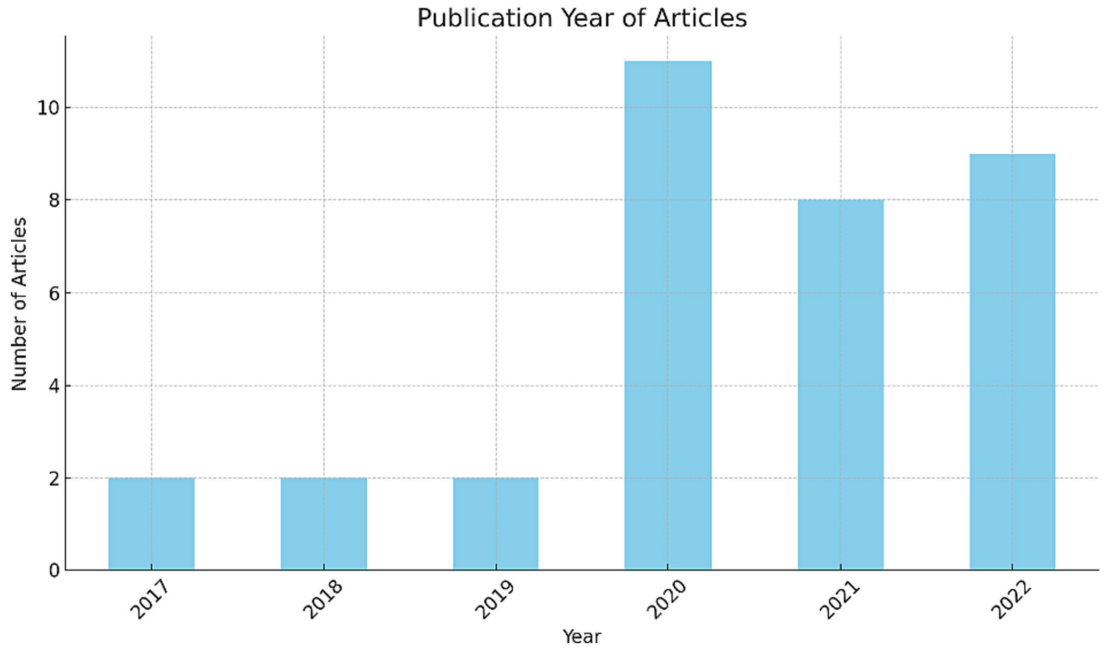

FIGURE 2
Number of articles by year.

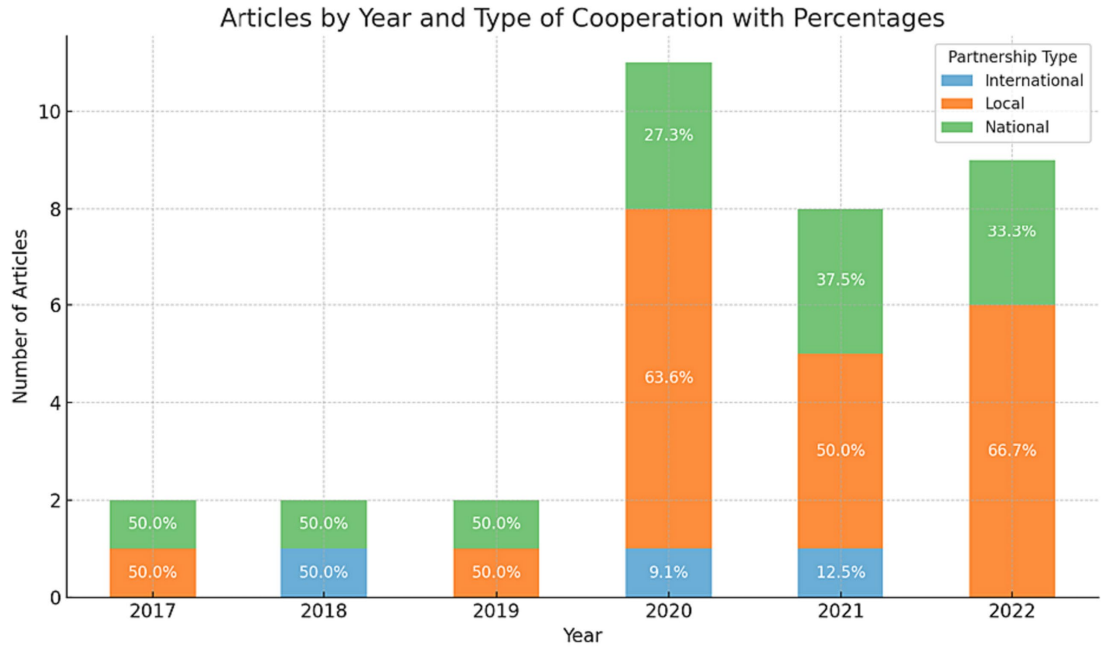

FIGURE 3
Articles by year and the distribution of author partnership.

events like the COVID-19 pandemic on research and publication rates, or changes in the data collection methods that might affect the reported numbers.

Figure 3 shows "Articles by Year and Type of Cooperation with Percentages." This figure provides a breakdown of articles published each year from 2017 to 2022, categorized by the type of cooperation involved: International, National, or Local. Each bar represents a year, and the segments in the bar represent the proportion of articles corresponding to each type of cooperation, with percentages indicated for each segment.

From 2017 to 2019, Figure 3 shows that there was an even 50–50 split between the distribution of author partnership. Local and

National cooperation in 2017 and 2019, and one research article with International cooperation in 2018. A notable shift occurred in 2020, with a decrease in National cooperation articles (27.3%) and the emergence of international cooperation articles (9.1%), while Local cooperation articles became the majority (63.6%).

In 2021, the distribution of articles was between local (50%), national (37.5%), and international cooperation (12.5%). By 2022, international cooperation articles had disappeared, and local cooperation articles grew to represent two-thirds (67.3%) of the total, while national cooperation articles made up one-third (33.3%).

The data suggests a shift in the landscape of research or project collaboration over the years, with a notable increase in national and international partnerships and a decline in local collaborations. The reasons behind this trend could be manifold, including the short time span since the PDC-framework were implemented, globalization of research efforts, funding availability, or strategic priorities shifting toward tackling global challenges that require broader collaborations.

Figure 4, "Number of Studies by Year and Percentage of longitudinal Studies," presents data for each year from 2017 to 2022, showing the number of studies conducted and distinguishing between longitudinal studies and non-longitudinal studies. Each bar represents a year, and within each bar, two segments are shown: one for non-longitudinal studies (in light blue) and one for longitudinal studies (in yellow), with percentages indicated on each segment.

The purpose of presenting the data in this way is to visualize the proportion of studies employing longitudinal analysis versus other types of studies across a six-year span.

In 2017 and 2018, all studies were non-longitudinal, as indicated by the 100% light blue segments in the bars for these years. A marked change occurs occurs in 2019, where 50% of the studies are longitudinal, shown by the emergence of the yellow segment. From 2020 onwards, there is a noticeable prevalence of non-longitudinal studies over longitudinal ones. In 2020, 63.6% of studies are non-longitudinal, and this trend continues with 75% in 2021 and 66.7% in 2022. The proportion of non-longitudinal studies has consistently remained above 60% from 2020 to 2022, indicating a strong and sustained interest in or need for non-longitudinal analysis in these years. These findings suggest there might be a need for an increasing emphasis on longitudinal studies, for understanding changes over time or the effects of PDC-interventions in various subject disciplines.

Figure 5, "Bubble Chart of Citations per Article" display three dimensions of data: the x-axis represents one variable (in this case, the Year of Publication), the y-axis represents another variable (Author names are listed here), and the size of the bubble represents the third variable (the number of citations per article). The chart is structured to show the distribution of citations that articles by various authors have received, plotted against the year those articles were published. The authors' names are listed on the y-axis, and the corresponding publication years are marked on the x-axis. The size of the bubbles indicates the relative number of citations received by the articles.

Certain authors, such as 'Gudmundsdottir et al.' and 'Instefjord and Munthe', have notably larger bubbles in specific years, which suggests that their articles have received a higher number of citations compared to others in the dataset. 'Gudmundsdottir' has the largest bubble, indicating a particularly high citation count for at least one article published around 2017. The distribution of bubbles across the years is relatively sparse, suggesting that not all authors have publications in every year within the range displayed. Although some authors, such as Brevik et al. and Damşa et al., have

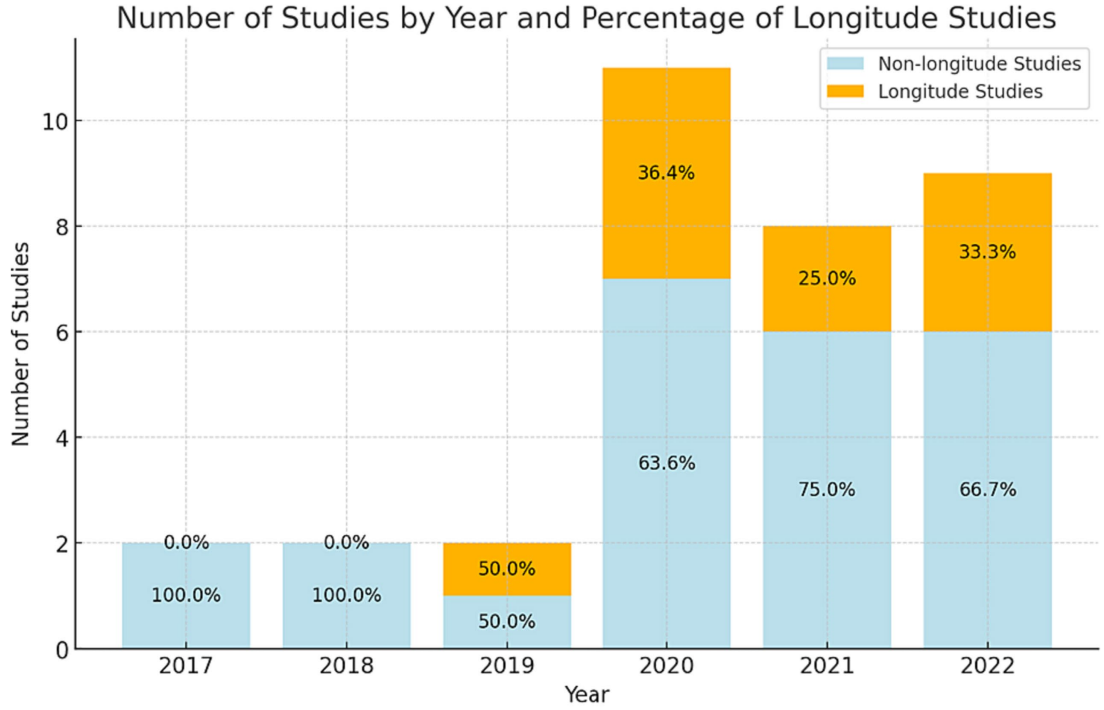

FIGURE 4
Articles with interventions (in yellow).

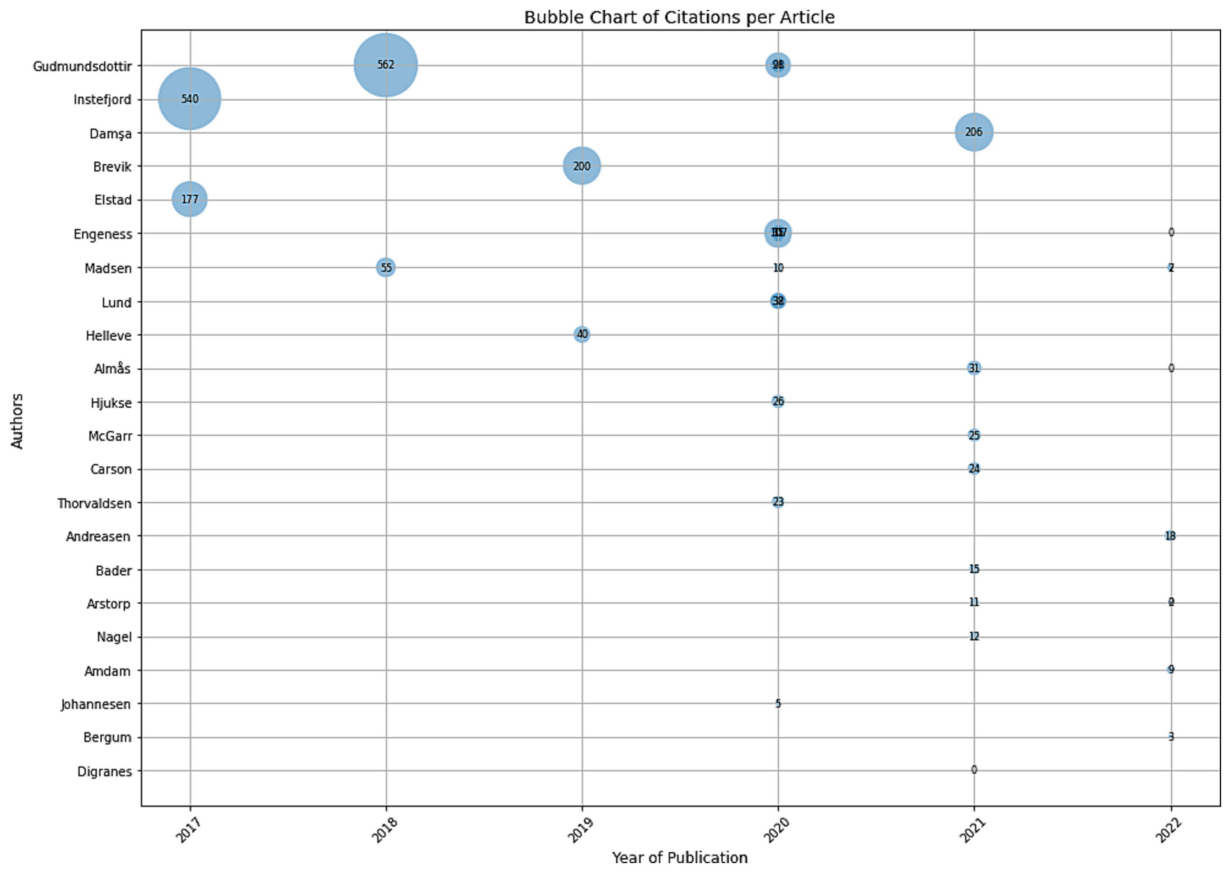

FIGURE 5
Number of the most cited articles distributed per year.

the highest number of citations for 2019 and 2021, their bubbles appear smaller, suggesting fewer citations per article compared to Instefjord and Munthe (2017) and Gudmundsdottir and Hathaway (2020). There is no clear trend in terms of time, as the bubbles do not show a pattern of increase or decrease in size over the years, indicating that citation counts do not necessarily correlate with the publication year in this sample. These findings could imply several things. For instance, 'Gudmundsdottir' and "Instefjord and Munthe 'might have published particularly influential or widely recognized work in the years where they have larger bubbles. The chart also suggests that citation counts are highly individual to the author and the specific work, rather than being tied to a particular time trend within this dataset. Since the PDC-framework was implemented only six years ago this also needs to be accounted for when considering this type of citation index. It could also reflect the impact of the journal the authors have published their articles in, the nature of academic influence, which does not necessarily grow linearly over time but can be affected by various factors such as the relevance of the topic, the reach of the publication, or the network of the authors.

Table 2 shows the complete table for number of citations per article arranged from highest cited to lowest cited. "Study nr" column, which is an identifier for each study, the "Cited" column indicates the number of times each study has been cited, the "Author(s)" column lists the authors of each study, and the "Year" column shows the year in which the study was published.

Table 2 illustrates that there is a wide range of citation counts, with some studies receiving a high number of citations, such as Study S19 with 562 citations and Study S24 with 540 citations, both of which suggest a significant impact in their respective fields. The studies with the highest citation counts were published in 2017 and 2018, which may indicate that they have had more time to accumulate citations or that they were particularly influential. Damşa et al. (2021) is the third most cited article and the most recent one of the top 10 most cited. This might indicate that this is a particularly influential or widely recognized work or that the theme (teaching during the pandemic) is a research field of growing interest.

There are several recent studies from 2021 and 2022 with fewer citations, which is expected since they have had less time to be cited. The table shows that Gudmundsdottir is a recurring author in highly cited studies, indicating that this author may be a prominent researcher or involved in significant work in their field. There are studies with zero citations (e.g., Study S6 and S16 from 2022), which could be due to the recency of their publication or their yet-to-be-recognized impact. The variation in citation counts across different years and authors might suggest differences in the visibility, reach, or influence of the respective studies.

This information can be valuable for evaluating the impact of PDC-research within an academic community, understanding trends in citation practices, and identifying key journals and key authors or works that are shaping the field.

TABLE 2 Complete table for number of citations per article.

Study nr	Cited	Author(s)	Year
S19	562	Gudmundsdottir and Hatlevik	2018
S24	540	Instefjord and Munthe	2017
S12	206	Damşa, Langford, Uehara, and Scherer	2021
S10	200	Brevik, Gudmundsdottir, Lund, and Strømme	2019
S14	177	Elstad and Christophersen	2017
S15	107	Engeness	2020
S20	91	Gudmundsdottir, Gassó, Rubio, and Hatlevik	2020
S31	55	Madsen, Thorvaldsen, and Archard	2018
S22	40	Helleve, Almås, and Bjørkelo	2019
S26	38	Lund and Aagaard	2020
S27	32	Lund, and Vestøl	2020
S18	31	Engeness, Nohr, Singh, and Mørch	2020
S4	31	Almås, Bueie, and Aagaard	2021
S21	28	Gudmundsdottir and Hatlevik	2020
S23	26	Hjukse, Aagaard, Bueie, Moser, and Vika	2020
S32	25	McGarr, Mifsud, and Rubio	2021
S11	24	Carson and Lund	2021
S34	23	Thorvaldsen and Madsen	2020
S2	18	Andreasen, Tømte, Bergan and Kovac	2022
S17	15	Engeness and Nohr	2020
S8	15	Bader, Iversen, and Burner	2021
S33	12	Nagel	2021
S7	11	Arstorp	2021
S28	10	Madsen	2020
S1	9	Amdam, Kobberstad, and Tikkanen	2022
S29	7	Madsen and Thorvaldsen	2022
S25	5	Johannesen and Øgrim	2020
S9	3	Bergum Johanson, Leming, Johannessen, and Solhaug	2022
S5	2	Arstorp	2022
S30	2	Madsen, Habbestad, and Borch	2022
S13	0	Digranes, Hoem, and Stenersen	2021
S3	0	Almås, Grov Nilsen, Helleve, Leer-Salvesen, and Gram	2022
S6	0	Arstorp	2022
S16	0	Engeness and Nohr	2022

The detailed overview in the Supplementary material shows the number of interventions and no intervention studies. Eleven studies with intervention and 24 with no intervention. Of the intervention studies, 4 of them were linked to government funding. This resulted in two qualitative studies (2021), one quantitative and one mixed (2022).

3.2.2 Methodological characteristics of included studies

Regarding the methodological characteristics, the first section present the research design distribution, the design segments by year and the number of interventions by design covers the Methodological paradigm. Subsequent are illustrations of the instrument data, the participants, the sample and the research perspective.

3.2.3 Methodological paradigm

Table 3, "Research design distributed by the number of sources" categorizes research studies based on their design: Mixed methods, Qualitative, and Quantitative. A comprehensive summary with all the details can be found in the Supplementary material. The columns in Table 3 represent the number of sources used in each study, with categories for studies using one source, two sources, or multiple sources.

TABLE 3 Research design distributed by the number of sources (see Supplementary material for full detail).

	Research design	One Source	Two sources	Multiple sources
Mixed	7	2	2	3
Qualitative	17	9	6	2
Quantitative	10	10		

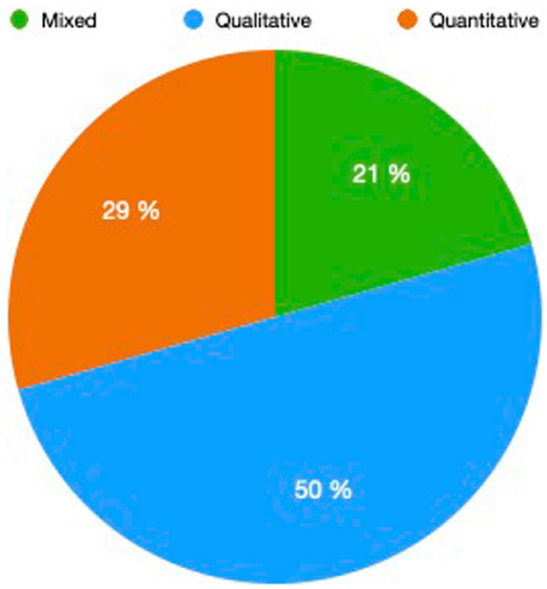

FIGURE 6
Pie chart of the different research designs.

Each cell in the table provides the count of studies that fit into both the category of research design and the number of sources used.

Regarding the nature of the type of study, Table 3 shows that qualitative design (17) is the most prominent followed by quantitative (10), while 7 studies used mixed methods. The articles with a mixed design had an equal distribution of sources (one, two, multiple). The studies with a quantitative design, most articles have only one source of data.

More specifically Table 3 shows that qualitative research designs are the most common, with the highest number of studies (17), but quantitative is using one source more than qualitative, if only by one. Quantitative designs are the second most common and are most frequently associated with using one source (all studies). Mixed methods designs are less common than qualitative but more common than quantitative when considering the use of two sources. Studies that utilize multiple sources are least common across all research designs, which might suggest a preference or a necessity for a more focused source base in the research field this table represents. There is a balanced distribution of mixed methods design studies across the number of sources used, indicating that mixed methods research may be more adaptable to different source availabilities.

This distribution could reflect the nature of the research questions being addressed within the field, where qualitative methods are preferred for in-depth exploration of a single source, or it could indicate resource constraints or methodological preferences among researchers. The findings could be useful for understanding methodological trends in this field and for guiding new researchers on common practices regarding source selection.

Figure 6, "Pie Chart of Research Design Distribution" shows a pie chart visually represents the distribution of research designs across a collection of studies. Each slice of the pie chart corresponds to a different research design category: Qualitative, Quantitative, and Mixed. The size of each slice reflects the proportion of studies using that research design.

The percentages are provided for each category, indicating the proportion they represent of the total.

Qualitative research designs constitute the largest proportion of studies, making up nearly half of the total (50%). Quantitative research designs represent a third of the studies (29%). Mixed methods research designs are the least common, making up 21% of the studies of the studies. The dominance of qualitative research suggests that in-depth, exploratory, or subjective approaches are prevalent in this PDC-field. The significant representation of quantitative research indicates that empirical, data-driven approaches are also valued. The smaller proportion of mixed methods research might suggest that integrating qualitative and quantitative approaches is less common, which could be due to a variety of factors such as complexity, resource requirements, or the nature of research questions that are being asked. These findings can inform researchers, funding agencies, and policymakers about the methodological preferences and trends within this research community.

Figure 7, "Stacked Bar Chart of Studies by Year and Research Design" displays the number of studies conducted each year from 2017 to 2022. Each bar represents a single year and is divided into segments that represent the number of studies employing each type of research design: Qualitative, Quantitative, and Mixed.

The colors assigned to each research design type are consistent across the bars, allowing for a comparison of how the use of each research design has changed over the years.

Qualitative research designs are consistently used every year and often represent the largest portion of the bars, suggesting that they are the most common research design among the studies represented. Quantitative research designs also feature prominently, although they appear to be less common than qualitative designs. Mixed methods designs are the least common overall but show an increase in later years, particularly in 2020 and 2022.

The distribution of research designs remains relatively consistent over the years, with qualitative research persistently being the most frequent. These findings may indicate a preference for or the suitability of qualitative methods in the educational field from which these studies are drawn. The increased number of mixed methods studies in the most recent years might suggest a growing recognition of the value of integrating different methodological approaches. The overall rise in the number of studies may reflect more awareness

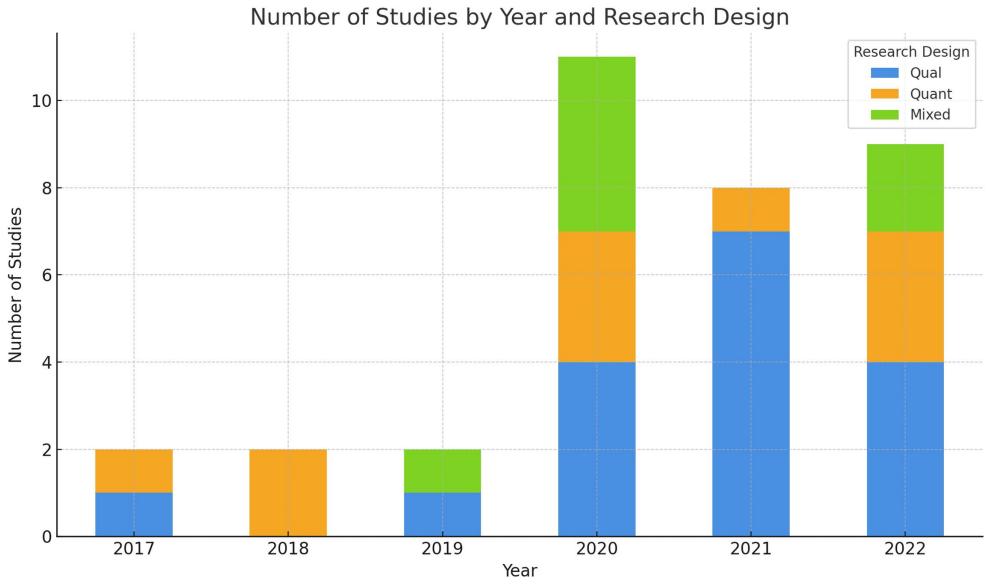

FIGURE 7
Percentage of studies by design distributed with year of publication.

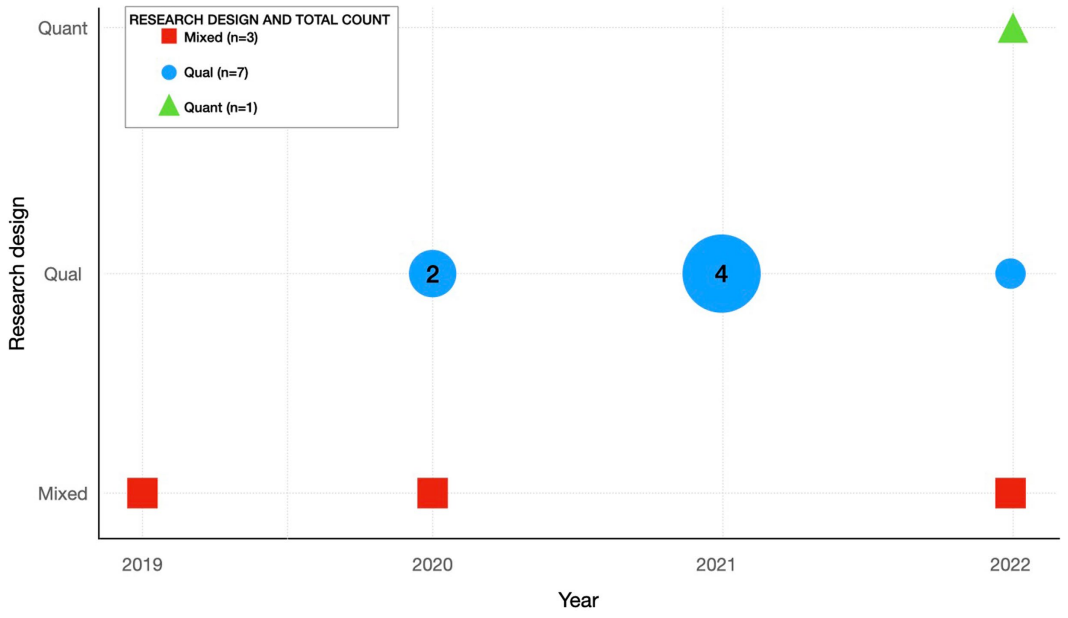

FIGURE 8
Number of intervention studies by year and research design.

around PDC, more research activity or increased funding and interest in this area.

Figure 8, "Number of Intervention Studies by Year and Research Design" shows that the x-axis represents the year of publication, ranging from 2019 to 2022.

The y-axis categorizes the type of research design used in the studies: Qualitative (Qual), Quantitative (Quant), or Mixed methods. The size of the bubbles indicates the number of studies employing each research design type in a given year. Different shapes or colors represent each research design type, which mentions Mixed ($n = 3$), Qualitative ($n = 7$), and Quantitative ($n = 1$) research designs.

The majority of the intervention studies appear to be qualitative, as indicated by the larger size of the bubbles in the "Qual" row. There are fewer quantitative studies overall, with only one quantitative study indicated by the small green triangle. Mixed methods studies are

represented but less frequent than qualitative ones, as indicated by the smaller red squares. There is a visible distribution of studies across the years, with no clear increasing or decreasing trend. This may suggest that the choice of research design does not follow a temporal pattern but is likely determined by the specific needs and context of each study. The chart does not indicate a significant change in research design preference over the years covered. This might suggest stability in the methodological approaches to intervention studies within this field or dataset. This visualization can help understand the methodological trends in intervention studies and may reflect the complexity of research questions being addressed, where qualitative methods might be preferred to explore nuanced, in-depth aspects of interventions. This is especially relevant since the PDC-framework has existed for only 6 years so far.

3.2.4 Instruments for data collection

Table 4, "Instrument data types" shows which details the types of data collection instruments used in various studies. The table lists different types of data collection methods ("Data Types") used in research studies. It provides a "Total" count of how many studies which applied each data type. The "Percentage" column shows the percentage that each data type represents out of all data collection methods used. The "Studies" column lists the specific studies (by their study number) which used each data collection method.

Surveys are the most commonly used data collection instrument, utilized in 11 studies and representing over 32% of the methods used. Interviews are the second most common method, used in 9 studies and accounting for approximately 26%. Policy documents, assignment responses, podcasts, and observation notes are also used, but less frequently than surveys and interviews. A variety of other methods are used only once across all the studies, suggesting a diverse range of data collection practices in the field. The high use of surveys and interviews indicates a preference for structured and direct methods of data collection, which can provide a broad quantitative and qualitative understanding of the research subjects. The variety of other methods used, although less frequent, points to a degree of methodological diversity and a willingness to employ different types of data collection to suit the particular needs of each study. The use of digital traces in LMS (Learning Management Systems) is particularly notable as it points to an interest in extracting data from digital platforms, which could be a growing trend due to the increasing digitization of learning environments and the use of learning analytics. The data in this table can be particularly insightful for researchers planning new PDC-studies, as it highlights common data collection practices and the potential for using multiple instruments to gather comprehensive data.

TABLE 4 Instrument data types.

Data Types	Total	Percentage	Studies
Survey	11	32,35	S02, S09, S12, S14, S16, S17, S18, S19, S20, S22, S29
Interview	9	26,47	S01, S03, S04, S08, S10, S21, S25, S26, S27
Policy documents	5	14,71	S06
Assignment response	3	8,82	S13, S16, S27
Podcast	2	5,88	S05 S11
Observation notes	2	5,88	S11
Study plans	1	2,94	S01
Strategic plans	1	2,94	S01
Allocation letter	1	2,94	S01
Reflection notes	1	2,94	S06, S07, S32, S33, S34
Analytics (digital traces)	1	2,94	S10
Teacher logs	1	2,94	S13
Student logs	1	2,94	S13
Photos	1	2,94	S13
Empirical snapshot	1	2,94	S15
Natural occurring	1	2,94	S25
Proposals	1	2,94	S26

TABLE 5 Samples and their distribution in the scoping review.

Pre-service teacher	20	19	Pre-service teacher only
In-service teacher	8	8	In-service teacher only
Teacher educator	8	8	Teacher educator only
Mentor teacher	2	0	Mentor teacher only
Project manager	2	1	Project manager only

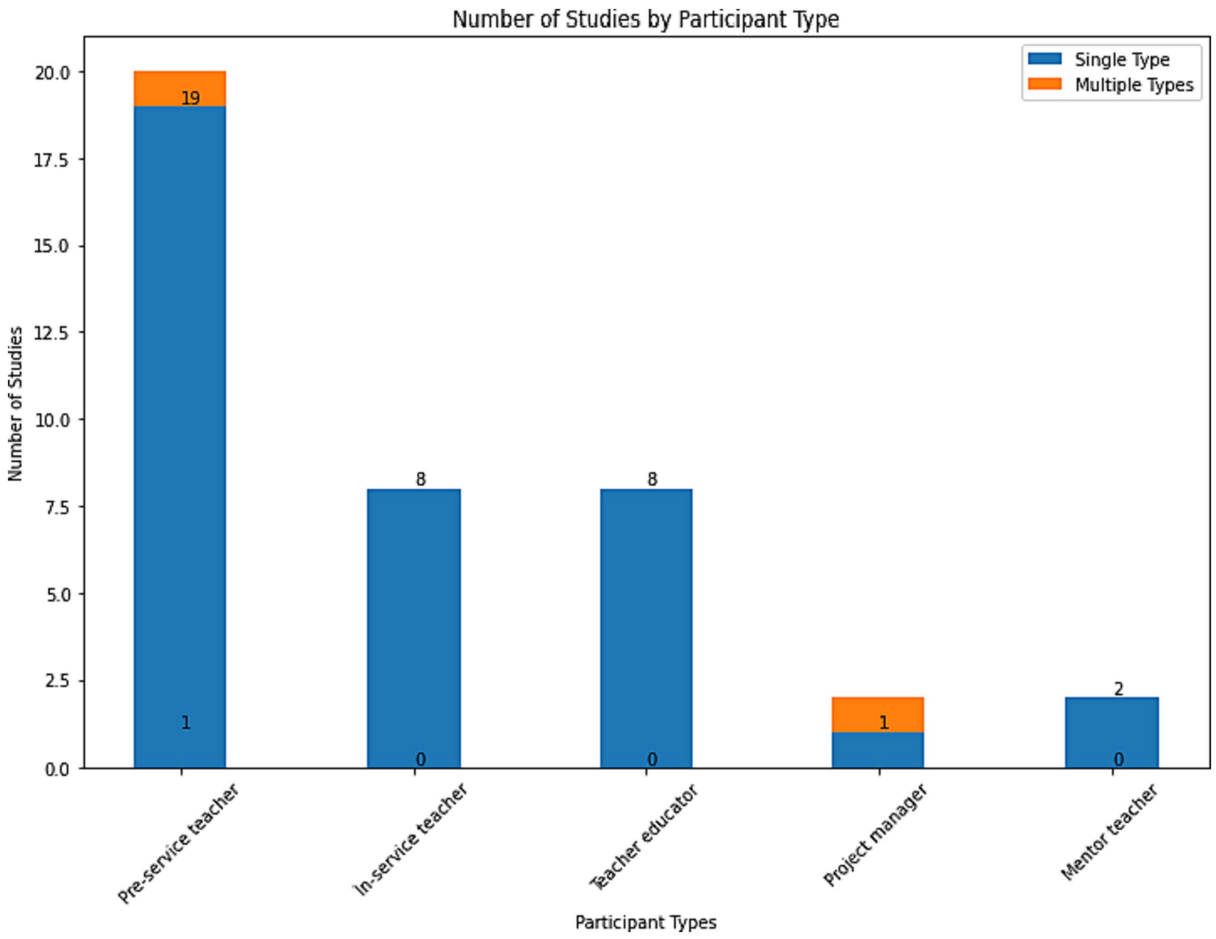

FIGURE 9
Distribution of studies that focus on a single participant type compared to those that include multiple participant types.

3.3 Size of sample

There are 27 studies with people as data (for a more comprehensive understanding, please refer to the Supplementary material). The average sample size is approximately 235 participants. The smallest sample size is 3 and largest is 1,244 participants. The standard deviation is about 271, indicating that there is a large variation in sample sizes among the studies. The large standard deviation and the difference between the mean and median suggest that a few studies with very large sample sizes may be skewing the average higher.

When assessing the distribution of studies that focus on one type of participant versus those that include multiple types in the sample, no studies exclusively focus on in-service teachers; they are always in combination with pre-service teachers. Similarly, no studies exclusively focus on mentor teachers; they are always in combination with others.

Figure 9, "Number of Studies by Participant Type" shows that the x-axis categorizes the participant types: Pre-service teacher, In-service teacher, Teacher educator, Project manager, and Mentor teacher. The y-axis represents the number of studies involving each participant type. The bars are color-coded to distinguish between studies focusing on a single participant type (indicated by the orange color) and those that include multiple participant types (indicated by the blue color).

From Figure 9, we can observe that pre-service teachers are the most frequently studied group, both alone and in combination with other participant types. Teacher educators also feature prominently, often in studies targeting multiple participant types. Project managers and mentor teachers are the least represented in the studies. Pre-service teachers are more commonly studied for the benefit of 1st order teacher development.

Teacher educators are commonly associated with studies aiming at 2nd order teacher development.

3.3.1 Participants involved in the research

Table 5, "Sample and their distribution in the scoping review" shows a list of various roles within the education sector and the number of studies from each sector that were included in a sample. The table categorizes studies by their professional role in the context of education. Next to each role is a number that represents the count of studies from that role who were part of a study's sample.

3.3.2 Sample

Pre-service teachers form the largest group in the sample, with 20 studies. This suggests that a majority of studies focuses significantly on those who are training to become teachers. In-service teachers and teacher educators are equally represented with 8 studies each, which implies a balanced interest in the perspectives of current educators

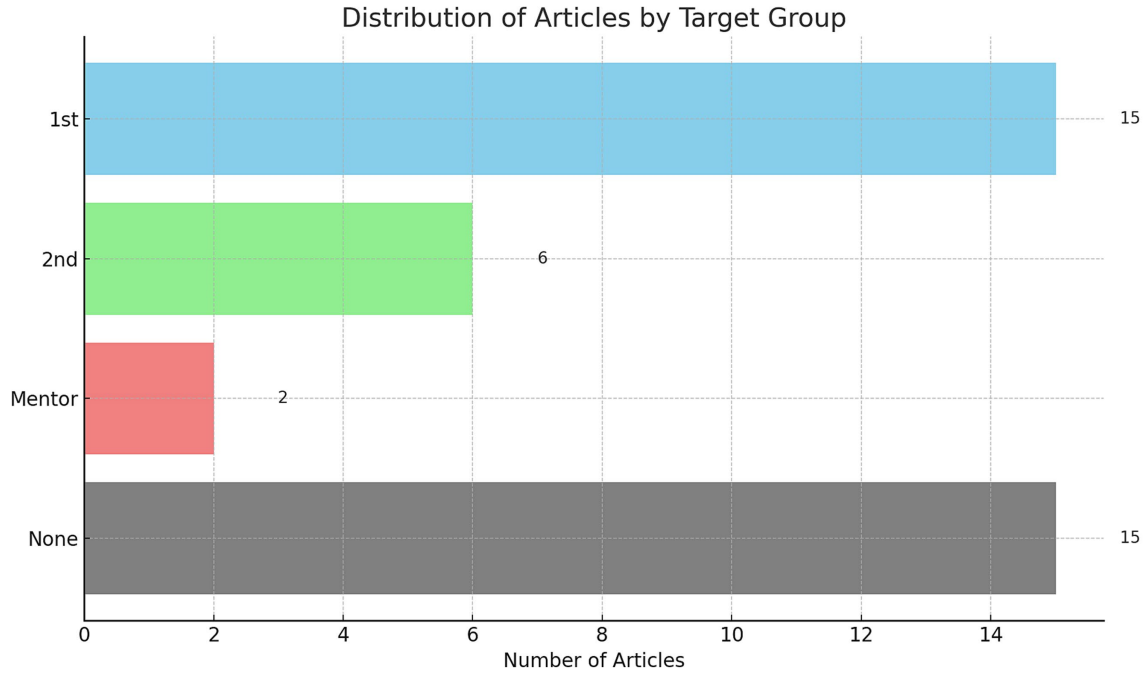

FIGURE 10
Distribution of articles by target group.

and those who train educators. There are smaller numbers of studies for mentor teachers, project managers, and other roles, indicating that these groups are less of a focus for the study or that they are less available for participation.

The table also lists categories that combine roles, such as "Student teachers, Teacher educators," which suggests that the studies might be looking at interactions or comparisons between different roles within the educational ecosystem. The presence of only 1 or 2 studies in several categories could mean that these perspectives are Supplementary material, providing additional insights rather than being the main focus of the research.

These findings can be useful in understanding the focus of the studies and the breadth of perspectives included. The heavy emphasis on pre-service teachers could indicate a research interest in the formation and education of future teachers. The data in this table can also be particularly insightful for researchers planning new PDC-studies, as it shows gaps in the research. For instance, how mentor teachers are an under-researched theme in the literature so far.

3.3.3 Research perspective

Figure 10, "Distribution of Articles by Target Group" categorizes articles by the target group of participants they studied: 1st order teachers, 2nd order teachers, mentors, and none (indicating no specific target group). Each horizontal bar represents one of these categories and the length of the bar shows the number of articles that focused on that particular group. The number at the end of each bar likely represents the count of articles in that category.

Out of the 34 academic articles, the target group distribution was mainly directed at first order teachers or none at all. Some were labeled with two categories (more comprehensive information on the studies included in the Supplementary material's overview.). Six articles were aimed at second order teachers and two at mentor teachers.

3.4 Research foci of included studies

The methodology of our investigation was meticulously structured around the comprehensive six-stage framework for scoping reviews as described by Arksey and O'Malley (2005). The initial stage of this framework required us to clearly define the research questions that would guide our inquiry, as well as establish the specific aims and breadth of our review. This foundational stage set the stage for a systematic exploration of the topic at hand and is detailed within the introductory portion of this scoping review. Subsequent stages, specifically stages two through four, involved a thorough search process across multiple databases. This allowed for the identification and meticulous selection of pertinent studies, which were then methodically charted to extract and organize relevant data. The final stage, stage five, involved the synthesis of this data. This synthesis process entailed a careful consolidation, summarization, and the synthesis of findings, which are presented comprehensively in the sections below.

3.4.1 Themes emerging

As mentioned, the methodology is delineated in alignment with stages two through five of the Arksey and O'Malley framework and these stages encompass the systematic strategies employed for database searching, study selection, charting of data, and the subsequent data synthesis that underpin the findings reported in this paper. Based on this process and analysis we find that the emergent themes in this scoping review are *Curriculum and integration, PDC reference and definition, Theoretical framework, Informing TEDs on operationalization of PDC and Dual didactical task.*

Table 6 shows a matrix of studies (identified by study number and author initials) and the different research approaches or themes

10.3389/feduc.2024.1363529

TABLE 6 The emergent themes.

#	Study (author)	Approaches				
		Curriculum and integration	PDC reference & definition	Theoretical framework	Informing PDC operationalization	Dual didactical task
1	Amdam, S. H.	X	X	X	X	X
2	Andreasen, J. K.		X	X		
3	Almås, A. G. (a)				X	X
4	Almås, A. G. (b)		X	X	X	
5	Arstorp, A-T. (a)		X	X		X
6	Arstorp, A-T. (b)	X	X	X		
7	Arstorp, A-T. (c)	X	X	X		
8	Bader, M.		X	X	X	
9	Bergum Johanson, L.	X	X	X		
10	Brevik, L.	X	X	X	X	X
11	Carson, L.			X		X
12	Damşa, C.		X	X		X
13	Digranes, I.	X		X		
14	Elstad, E.	X	X	X		
15	Engeness, I. (a)		X	X	X	X
16	Engeness, I. (b)		X	X	X	
17	Engeness, I. (c)		X	X	X	
18	Engeness, I. (d)		X	X	X	X
19	Gudmundsdottir, G. (a)		X	X		
20	Gudmundsdottir, G. (b)		X	X		
21	Gudmundsdottir, G. (c)		X	X		X
22	Helleve, I.		X	X		X
23	Hjukse, H.	X	X	X	X	X
24	Instefjord, E.		X	X		
25	Johannesen, M.	X	X	X	X	
26	Lund, A. (a)		X	X		X
27	Lund, A. (b)		X	X		
28	Madsen, S. S. (a)	X	X	X		
29	Madsen, S. S. (b)		X	X		
30	Madsen, S. S. (c)			X		X
31	Madsen, S. S. (d)	X	X	X		
32	McGarr, O.	X	X	X		
33	Nagel, I.	X	X	X		
34	Thorvaldsen, S.	X	X	X		

addressed within these studies. The approaches/themes are listed as column headers *Curriculum & integration, PDC reference & definition, Theoretical framework, Informing PDC operationalization, Dual didactical task*. An "X" marks the intersection of a study and the approach/theme it includes, indicating that the particular study addresses that specific aspect.

From Table 6 we can see that several studies focus on more than one theme, with some addressing up to four or all five of the listed themes. The most common themes across these studies seem to be "Theoretical framework" and "PDC reference & definition," indicating these are key areas of focus in this research field. "Curriculum & integration" and "Dual didactical task" are less frequently addressed, but still significant as they appear in multiple studies. The variety in the number of themes addressed by each study suggests a range of depth and focus areas. Some studies may take a more holistic approach by covering multiple themes, while others are more specialized. The "Informing PDC operationalization "theme is relatively less addressed compared to others, which could imply that there is already an established understanding of this concept among the studies, or it is not the primary focus.

This Table 6 provides a useful overview of the research landscape, showing which themes are most commonly explored and which may require more attention or are emerging PDC-areas of interest.

3.4.2 Theme 1: policies and curriculum

One contribution to the discourse is research examining how digital competence is addressed in curricula, program plans and policy documents. These articles touch on what is expected of teacher educators (TEDs) and how policy documents shape the understanding of Digital Competence and teachers Professional Digital Competence.

Figure 11 is a timeline visualizing the development of teacher education policy and curriculum in Norway. It is categorized into two main sections, "Policy" and "Curriculum," with key milestones and initiatives plotted across a timeline from 1980 to 2020. Different colors and markers indicate specific periods or initiatives, such as different versions of the National Curriculum for Teacher Education, and the introduction of the Professional Digital Competence (PDC) framework.

The timeline indicates a clear progression and evolution of teacher education policy and curriculum in Norway, with several revisions to the National Curriculum over the decades.

The introduction of PDC as a concept is a relatively recent development in the educational landscape, which suggests an acknowledgment of the growing importance of digital competence in the teaching profession. There appears to be a consistent effort to update educational policies and curricula, which may reflect ongoing changes in educational standards, technology, and societal needs. The intervals between revisions of the curriculum seem to shorten toward the latter part of the timeline, potentially indicating an accelerating pace of change in education and a need for more frequent updates to keep teacher education relevant.

3.4.3 Theme 2: PDC references and definitions

Intellectual sources are "The knowledge base of a field is the set of articles most cited by the current research. » (Persson, 1994, read in Zupic and Čater, 2014). The top sources cited in the articles are Kelentrić et al. (2017) and Mishra and Koehler (2006), each cited in 7 articles. Brevik et al. (2019), Gudmundsdottir and Hatlevik (2018), and Lund et al. (2014), are cited in 6 articles. Redecker and Punie (2017), cited in 5 articles. This indicates these sources are highly influential in the field of Professional Digital Competence. Kelentrić et al. (2017) and Mishra and Koehler (2006), and Redecker and Punie (2017) are frameworks. The other top cited intellectual sources are research studies.

Figure 12 presents a directional network graph of the intellectual sources, where each node (dot) represents a distinct intellectual source, in this case, the articles in query. The citations between these sources are depicted as direct edges (lines) indicating the flow of information from one source to another. In this network graph, nodes that are highly cited (with many incoming links) demonstrate scholarly influence, as they are often foundational or significant in their field. Nodes that cite widely (with many outgoing links) can be seen as central conduits of information and may contribute to the integration of knowledge across different areas of research (Granovetter, 1973).

The network graph also reveals clusters of intellectual sources that are commonly referenced together, suggesting these works are related either thematically or conceptually within the body of literature. The distribution of the nodes and the patterns of co-citation could be used to identify subfields or dominant conversations within the broader research area. Peripheral nodes with fewer connections might represent emerging areas of research or more specialized topics within the field. An interactive version of this network graph is available at https://public.flourish.studio/visualisation/16863714/.

As for definitions, the field of Professional Digital Competence in teacher education is in its formative years, with no consensus on a definitive description, mirroring a multifaceted landscape, diverse theoretical frameworks, research methodologies, and practical applications. This is also reflected in the papers in this study where some refer to the Norwegian framework as the definition of PDC while others refer to forefront scholars in the field, like Mishra and Koehler (2006), Lund et al. (2014), Røkenes and Krumsvik (2016) or Brevik et al. (2019).

3.4.4 Theme 3: theoretical frameworks

The theoretical landscape represented in the papers covers a broad range of theoretical perspectives on digital competence, spanning from the cognitive experiences of individuals to the wider societal and cultural contexts.

The sociocultural perspectives, such as Activity Theory and Cultural-Historical Research Approaches, focus on learning through social interaction and cultural mediation. These perspectives

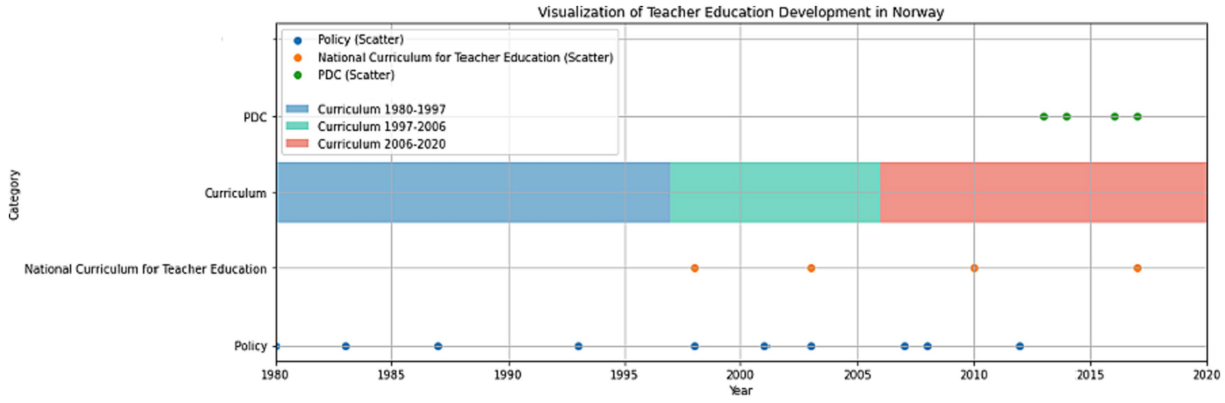

FIGURE 11
Policy and teacher education development in Norway.

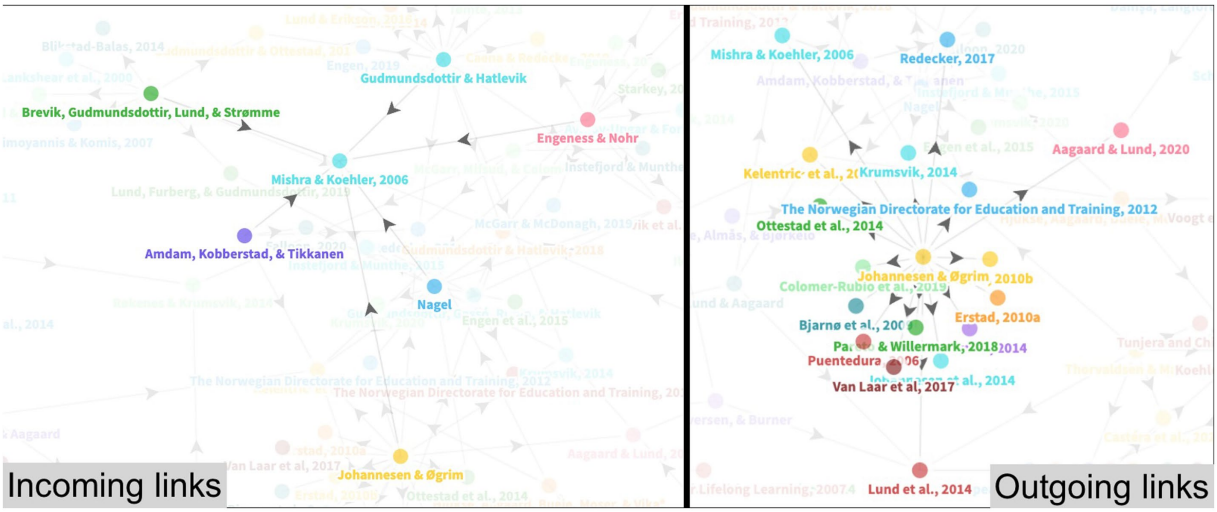

FIGURE 12
Network graph with examples of incoming and outgoing links.

emphasize the community-based aspects of learning and highlight how digital competencies are developed in context. Self-Efficacy, as proposed by Bandura, and Galperin's Pedagogical Theory provide insights into an individual's capacity and strategies for engaging with digital tools. They emphasize personal agency and the cognitive processes involved in acquiring skills. The Social Constructivist Learning Theory and the concept of Transformative Agency explore how learners construct knowledge and adapt to digital challenges. This requires a dynamic interplay between agency and the constantly evolving digital landscape.

In summary, this array of theories offers a valuable perspective for investigating digital competence, incorporating the roles of both personal and community factors in learning. Nonetheless, the diversity and overlap of these theories add a level of complexity that researchers must manage when exploring this multifaceted area of study.

3.4.5 Theme 4: informing PDC operationalization

In exploring the operationalization of Professional Digital Competence (PDC) within Teacher Education (TE), several themes emerge, highlighting the diverse approaches and challenges teacher institutions and educators face. From strategic intent to pedagogical application, and the evolving nature of PDC.

Strategic Differences: There is a notable variation in how TE institutions incorporate PDC development into their strategic documents and program plans. This could suggest that the approach to PDC is not uniform and is subject to differing interpretations and applications (Arstorp, 2021; McGarr et al., 2021; Amdam et al., 2022).

Institutional Impact: Teacher education institutions play a crucial role in shaping the PDC beliefs of Pre-Service Teachers (PSTs). Workshops and collaborations among PSTs, in-service teachers, and university faculty, are significant in this development. However, there is an indication that some educators may undervalue their need for PDC development (Almås et al., 2021).

Underutilization of Digital Resources: Digital resources that could potentially enhance PDC are not widely used within TE. This under-use might be contributing to a lack of awareness and reflection on PDC among student teachers (Bader et al., 2021).

Starting Point in TE: Student teachers often come into TE programs with a strong foundation in digital competence. However, there seems to be a disconnect where TE programs may not effectively build upon these existing competencies (Almås et al., 2021).

Bridging the gap: Closing the gap between theory and practice with metacognitive reflection and development, i.e., ethical perspectives, pedagogical use, self-regulatory practices (Bader et al., 2021; Almås et al., 2022; Arstorp, 2022).

Concept in the Making: PDC is an evolving concept, and student teachers may struggle with grasping its complexity and relevance to their professional development. TE programs need to create opportunities for students to understand and reflect on the strategic use of digital tools in education.

3.4.6 Theme 5: teacher educators' dual didactical role

Dual didactical task refers to the challenge of integrating two separate goals or aspects into teaching, and this is a complex yet essential challenge for teacher educators. In our context it refers to the need for teacher educators to develop their own professional digital competence while simultaneously promoting the development of this competence among their students (Lindfors and Olofsson, 2023).

One takeaway is the acknowledgment that TE not only need to support from their institution to the advancement of TEDs own PDC, but also ensure that the TEDs are well-equipped to model and teach this competency (Lund et al., 2014; Thorvaldsen and Madsen, 2020; Bader et al., 2021).

According to Arstorp study (Arstorp, 2022) students in "future classroom labs" (FCL) or "learning labs" start off with a student perspective, but over the course of their employment in the FCL, they develop a new perspective (a development perspective), giving them a unique, dual perspective as both student and teacher educator. This dual perspective allows student assistants to contribute to both overcoming the student-educator dichotomy and bridging elements of the theory-practice gap.

Amdam et al. (2022) claims student assistants (in labs) bring a unique dual perspective to the table, as they are both learners and

educators. This dual perspective allows them to contribute significantly to the development of PDC in teacher education.

4 Discussion

4.1 RQ1 – what is known about the implementation of PDC in TE?

As the numerical and thematical analysis of the studies show: Professional Digital Competence in teacher education is diverse and multifaceted and there are gaps in the current state of knowledge.

- There is a need for increasing emphasis on longitudinal studies, for understanding changes over time or the effects of PDC-interventions in various subject disciplines.
- a majority of studies focus significantly on those who are training to become teachers.
- mentor teachers are an under-researched theme in the literature.
- No studies exclusively focus on in-service teachers; they are always in combination with pre-service teachers. Similarly, no studies exclusively focus on mentor teachers; they are always in combination with others. Out of the 34 academic articles, the target group distribution was mainly directed at first order teachers or none at all.

The data and illustrations in the numerical analysis provides a useful overview of the research landscape and can be particularly insightful for researchers planning new PDC studies.

Findings unfolding from the themes substantiate that PDC in teacher education is multi-dimensional.

For curriculum and integration, we find strategic differences in how teacher education institutions incorporate Professional Digital Competence development. While several included articles report on government-funded projects where a few institutions received funding to cultivate PDC, this contrasts with the broader landscape where many institutions must navigate without such support. Despite not delving into the direct effects of these funded initiatives, the literature implies their positive impact (Almås et al., 2021; Nagel, 2021; Amdam et al., 2022; Andreasen et al., 2022). This disparity highlights the necessity for all teacher education institutions to intensify efforts in PDC development, as they are crucial in shaping the future of educational technology engagement and application.

For *PDC reference and definition*, it highlights how PDC is conceptualized and understood within the academic community. Our study delves into how Professional Digital Competence is variously defined and referred to in literature, revealing a range of interpretations that affect how it is approached in educational settings. Our proposal of a common definition is a timely contribution to the field of teacher education, responding to the need for a unified understanding of what it means to be digitally competent in a professional teaching context.

We also find that the *Theoretical Frameworks* and the different theoretical underpinnings that guide the integration and understanding of PDC, vary and are sometimes quite vague. These theories provide a comprehensive lens to examine the development of digital competence, acknowledging both the individual and collective influences in the learning process. Nonetheless, the diversity and overlap of these theories add a level of complexity that researchers must manage when exploring this multifaceted area of study. There seems to be a need for strengthen the theoretical underpinning of PDC by exploring various educational theories and how they intersect with digital competencies and PDC.

Informing teacher education programs on *PDC operationalization* focuses on practical ways to embed digital competence in teaching practices. This is the less-explored theme in our review. This aligns well with previous research indicating that teacher education institutions continue to grapple with the integration of Professional Digital Competence into their curricula. The emphasis on the *dual didactical task* underscores the challenge of balancing digital skill development with pedagogical effectiveness, a critical consideration for modern educators. Attaching Teacher educators into the mix adds another layer of complexity. According to Uerz et al. (2018), an important prerequisite is to "substantiate the underlying pedagogical and educational choices". We propose the following model as a scaffold for teacher educators when implementing PDC in TE (Figure 13).

The PDC ladder for TE is a simple framework designed to guide the educator from a subjective viewpoint, trimming down the complexity of this multifaceted concept. There are three levels, like on a ladder, representing the pupils, the teachers, and the teacher educators. The bottom level covers the digital skills pupils are anticipated to know from school. The middle level is the Professional Digital Competence that teachers are expected to know. The top level is the important part and scaffold for the TE. The teacher educator needs to model and communicate meta learning about the layer beneath. As an example, we use the Starkey PDC model (Starkey, 2020) for the middle layer, indicating that TEDs need to model how to manage the digital learning environment as well as communicate in a meta-cognitive way with the teacher students: an emphasis on metacognition and modeling, vital for teacher educators for developing their students Professional Digital Competence. The model draws on the findings from this scoping review as well as Uerz article on "Teacher educators' competences in fostering student teachers' proficiency in teaching and learning with technology" (Uerz et al., 2018). The framework is adaptable in terms of what you put in the two bottom layers is aligned with the relevant curriculum from the subjective viewpoint.

4.1.1 RQ2 in what way is previous research informing TEDs on the operationalization and implementation in TE in Norway?

The research´ ability to Inform Teacher Education Programs on PDC Operationalization focuses on the practical application of PDC in teacher education. The complexity of the frameworks appears to be a hindrance. It seems to be a need to narrow down this complexity of the framework and develop more sustainable strategies and methods for effectively incorporating PDC into teaching methodologies in TED. Particularly the *Dual Didactical Task* emphasizes the challenge faced by educators in integrating PDC while maintaining effective pedagogical practices. It involves balancing the technical aspects of digital competence with educational principles to enhance teaching and learning, and our study shows the need for professional development within this area.

Students develop their Professional Digital Competence through specific technologies, didactical experiences and by working with PDC during TE (Almås et al., 2021). Based on the findings from this scoping review, there still is a gap between mastering digital skills and the broad scope of Professional Digital Competence for pre-service teachers. The students tend to overestimate their understanding of digital

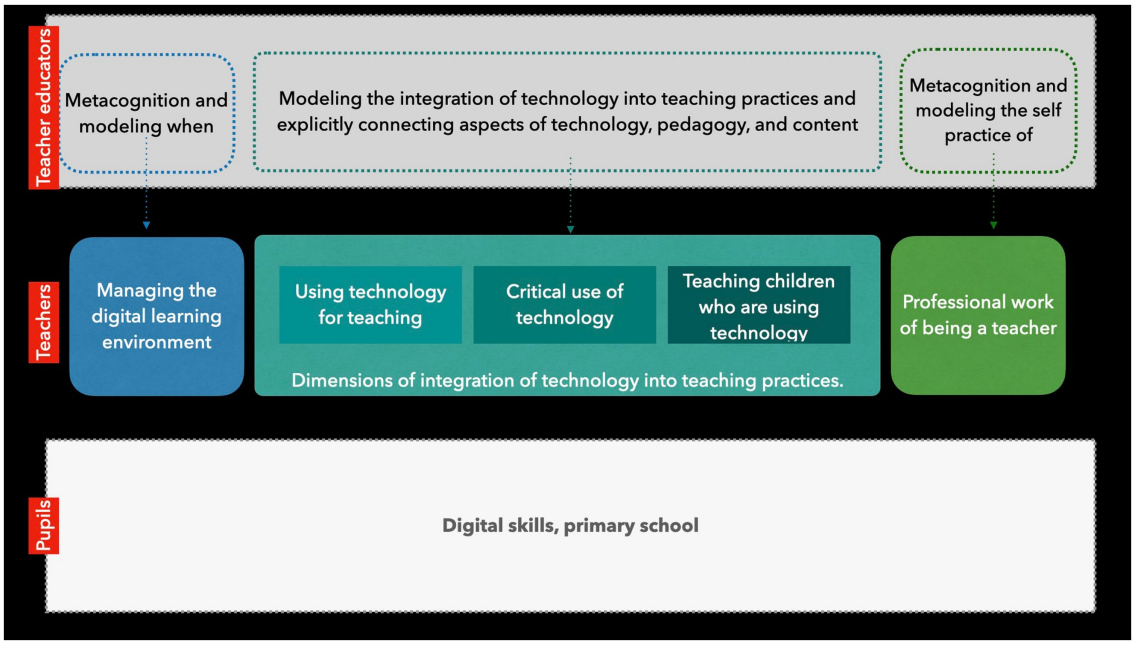

FIGURE 13
PDC ladder for TE.

competence (Almås et al., 2021), men more than women (Andreasen et al., 2022). This means TE needs to focus on the meta-perspective when using technology for teaching and learning (Nagel, 2021).

PDC consists of 7 competency areas, each quite comprehensive on its own. Additionally, within this framework, there are more than 50 descriptions of learning outcomes. This makes the framework quite complex, somewhat cluttered, and ambitious. This complexity seems to contribute to the wide range and scope of studies conducted so far. The implication of such complexity for teacher educators is also that the framework is too hard to implement in their everyday practice in teacher education. Therefore, is seems to be a need for revising this framework by reducing the number of competence areas and learning outcomes. This will probably narrow the scope of the studies, strengthen the current state of knowledge, and make it more realistic for TEDs to implement PDC in their everyday practice.

One initiative mentioned in three articles (Amdam et al., 2022; Andreasen et al., 2022; Arstorp, 2022) is learning labs and student assistants. Both these interventions expose students to a broad range of digital technologies, and to developing new perspectives.

4.1.2 RQ3 what focus on support for transferring existing competence to new technology

The literature indicates a need for teacher education to evolve. Educators need to adapt to a society that is increasingly digitalized. Often using tools that are not designed for educational purposes. As of writing, Ai has entered the school system with its advantages and disadvantages. This transformative change happened only a short time after computational thinking was embedded in the national curriculum in Norway. The focus the current state of knowledge has on transferring existing competencies to new technologies is therefore of importance (Aagaard and Lund, 2019; Brevik et al., 2019; Lund et al., 2019). Emphasizes that engaging in transformative digital agency enables the creation of educational designs that are relevant to new technologies. This involves also being able to identify complex situations and conceptualize alternative futures. Damșa et al. (2021) builds on the framework of Brevik et al. (2019) and claims their multidimensional analytical framework "has potential to capture the nuances in agency manifestations in any context (including action during crises)" (Damșa et al., 2021) in addition, Thorvaldsen and Madsen (2020) advocates the DLL (Double Loop Learning) process, conceptualized by Argyris and Schön, provides a framework that involve educators rethinking their pedagogical approach in light of new technologies.

Overall, the shift toward enhancing digital competency in teacher education is imperative, ensuring educators not only keep pace with current technology but also adapt to future educational challenges.

4.2 Conclusion

In conclusion, this review on Professional Digital Competence (PDC) in Norwegian teacher education reveals a multifaceted landscape. The diverse theoretical frameworks, research methodologies, and practical applications discussed in the reviewed papers underscore the complexity of integrating digital competence in teacher education. The findings suggest a growing recognition of PDC's importance but also highlight the challenges in standardizing and implementing it effectively. This review calls for further research to refine PDC's conceptual understanding and to develop comprehensive strategies for its integration, aiming to enhance the digital readiness of future teachers in a rapidly evolving educational landscape.

More specifically, the investigation into PDC within Norwegian teacher education not only reveals diverse interpretations and applications of PDC but also underscores its critical role in

contemporary teaching paradigms. The review highlights the need for a more cohesive and standardized approach to integrating digital competencies in teacher training programs. It suggests the necessity for ongoing research to keep pace with technological advancements and evolving educational needs. This study advocates for a collaborative effort among educators, policymakers, and researchers to develop robust, adaptable frameworks for PDC. Such efforts are essential for preparing future teachers to effectively navigate and leverage digital tools in an increasingly digitalized educational landscape.

This review and the current state of knowledge shows the need for more specific directions for future research and practical strategies for implementing PDC in teacher education, emphasizing its significance in enhancing teaching quality and student learning outcomes in the digital age.

Across the studies we also find a tendency that these underscore that Norwegian frameworks such as PDC do not arise in a vacuum, and there is a lack of highlighting other earlier Norwegian models/frameworks that were the prelude to PDC. This is particularly notable since a majority of the studies are conducted in the Norwegian educational context where the former models/frameworks also are for. This seems to be important to highlight in the following years and will contribute to a more nuanced perspective around the PDC-concept's historically, semantical and research-based development.

4.3 Study limitations

The final search for primary studies was March 23, 2023, and there is a limitation in the study for studies that were potentially published after this date.

Another limitation of the study is that while Arksey and O'Malley's framework includes a sixth stage–engaging in a consultation exercise with stakeholders to inform or validate study findings–this step was not incorporated into the present study.

4.4 Implications for teacher education

4.4.1 Future research

For future research, it is recommended to broaden participant profiles, including more teachers and field instructors, to gain a wider perspective on Professional Digital Competence (PDC) implementation. Additionally, involving more diverse groups of educators, like mentor teachers and initial teacher educators, could provide deeper insights into PDC's practical application and challenges in various teaching environments. It seems also to be a need of more Mixed method studies.

Author contributions

SN: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. RK: Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. FR: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1363529/full#supplementary-material

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