



The role of multidisciplinary in developing teachers' professional digital competence

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Abstract

In this article, we describe how multidisciplinary activities in a teacher education programme fostered the development of student teachers' professional digital competence. Based on naturally occurring and interview data, the authors present three distinct periods of Norwegian teachers' education with a focus on developing professional digital competence required by national and local regulations; we then present the OsloMet teacher education programme multidisciplinary activities that take place during these three periods. We discuss how various implementation approaches support student teachers' professional digital competence (PDC) in particular teaching of, with and about technology. The authors conclude that locally implemented material structures are crucial to implementing student teachers' professional digital competence and arranging for emerging transdisciplinary activities. As such, student teachers' PDC can be described as a well-orchestrated system of multi-, inter- or transdisciplinary activities that develop student teachers' competencies in teaching of, with and about technology.

Keywords: teacher education; professional digital competence; multidisciplinary; transdisciplinarity; material structures

Introduction: In search of the professional teacher

Fenwick (2016, p. 37) noted that 'most researchers agree that professionalism is highly nuanced and multifaceted – even pluralistic', but it is defined differently by different professional groups. The ongoing debate about teaching (Darling-Hammond & Lieberman, 2012) portrays the complex and diverse perspectives of the teacher profession. To prepare students for a continually changing society both teachers and students need to achieve new competencies. Such competencies, often called 21st-century skills (Flynn, 2014; P21, 2002) are characterised

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by creativity, communication, collaboration and critical thinking, overarching traditional subject-specific knowledge domains. Many 21st century competencies have resulted from the emergence of complex information and communication technologies and, therefore, require digital competencies.

Mastering digital tools, working within and understanding a digitalised society have been and will continue to be integrated into the educational system. Hence, teachers' professional digital competence (PDC) is crucial. Contemporary literature on teachers' PDC is strongly influenced by the works of Mishra and Koehler (Mishra, 2019; Mishra & Koehler, 2006b) and of European/Scandinavian researchers (Colomer-Rubio et al., 2019; Johannesen et al., 2014; Krumsvik, 2014; Lund et al., 2014; Ottestad et al., 2014; Redecker, 2017), all striving to illustrate the complex knowledge that pedagogical use of digital tools in education demands.

In Norway, the Knowledge Promotion (LK 06) national curriculum reform for primary and secondary education (Ministry of Education Research and Church Affairs, 2006, p. 12) introduced five competencies needed in all subject areas: whereas the use of digital tools was one. This necessitated multidisciplinary teaching activities for the integration of digital competencies into all subject areas.

Teacher education (TE) programs in Norway addressed the need to develop student teachers' PDC to prepare them to facilitate students' digital competencies in multiple ways (Tømte et al., 2013). In this article, we present an analysis of the history of OsloMet TE and the struggle to educate teachers for the future within the frames of national curriculums by addressing the following question: *What role does the implementation of multidisciplinary activities in a teacher education programme play in developing teachers' professional digital competence?*

Theoretical framework

To understand the role of multidisciplinary in the development of student teachers' PDCs, we first examine the concept of *multidisciplinary* and its *relation to interdisciplinarity* and *transdisciplinarity*. We then argue for interpreting student teachers' PDC as mastering the *teaching of, with* and *about technology* and thereafter employ these concepts to analyse the role of multidisciplinary in developing teachers' PDCs.

Multidisciplinary

Discipline-based educational practices are being challenged by more holistic approaches, often called multidisciplinary, interdisciplinary and transdisciplinary strategies (Drake & Burns, 2004), because most service and information sector jobs require high levels of general skills and transversal competencies (Finegold & Notabartolo, 2010; Greenlaw, 2015; Nenseth et al., 2010).

Multidisciplinary, interdisciplinary and transdisciplinarity can be confused as interchangeable terms (McClam & Flores-Scott, 2012), but the literature distinguishes the meanings of the terms, which differ within disciplines. Rowland (2006) stated that multidisciplinary approaches involve discipline experts contributing expertise and working together on problems in pursuit of individual goals, whereas interdisciplinary strategies involve experts providing input to address problems together in pursuit of a common goal. Rowland

(2006) said transdisciplinary approaches require that traditional disciplinary conventions should be left behind, and new forms of knowledge emerge. Drake and Burns (2004) defined the three categories similarly: the multidisciplinary approach integrates different disciplines so that the standards of each are organised around a common theme; interdisciplinary approaches involve organising the curriculum around common themes and then addressing what is embedded in disciplinary standards; transdisciplinary approaches do not use the disciplines as points of departure, but instead base lesson content on students' questions and concerns in a real-life context. Choi and Pak (2008) reviewed health, services, education and policy research literature, seeking to define the terms. They concluded that:

Multidisciplinarity draws on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole. Transdisciplinarity integrates the natural, social and health sciences in a humanities context, and transcends their traditional boundaries. (p. 351)

The primary school context frequently involves interdisciplinarity, although implemented in diverse and somewhat blurred ways (Kristensen, 1987). Such implementations range from what was previously presented within the realms of multidisciplinary (within the boundaries of the subject area) and interdisciplinarity (as a coherent whole) to problem-based learning, which may be perceived as transdisciplinarity. However, what constitutes multidisciplinary has not been clearly defined (Borg et al., 2015). One understanding emphasises professionals from different disciplines cooperating in teams; another focuses on cooperation between subject areas in interdisciplinary activities. In an educational setting, new practices may develop on the borders of the fields of study involved in multidisciplinary activities (Borg et al., 2015).

In a Norwegian context, OsloMet TE employs the term multidisciplinary, incorporating project *Fleirfagleg* (multidisciplinary) (Michelet et al., 2004) activities in curriculum plans. According to the findings of the current study, the practical implementation of multidisciplinary activities was a core material structure for developing student teachers' digital competence. As stated in the study report:

For many participants 'multi-disciplinary' have been a focus for gradual development of thematic cooperation in more modest forms than the earlier cooperation strategies which focused primarily on the introduction of inter-disciplinarity and [study] weeks where project work would dominate (Michelet et al., 2004, p. 101).

This multidisciplinary demands strong cooperation across subject areas through coordinating and exploiting complementary competencies, without permanent subject integration as a goal (Borg et al., 2015). OsloMet's TE programme has for years arranged for such material structures to develop student teachers' digital competencies as curriculum-based binding cooperation between subject areas on learning about and using digital tools in all subjects. These material structures appear as multi-, inter- and transdisciplinary activities. Consequently, we wish for investigating the role of these multi- inter- and transdisciplinary material structures in developing teachers' PDC.

Teachers' professional digital competence – teaching of, with and about technology

Policy- and research-based definitions of digital competence have emerged over the past decade (see for example Erstad, 2010a; Ferrari et al., 2014), as have definitions of digital competence in schools (Bjarnø et al., 2009, 2017; Erstad, 2010b; Utdanningsdirektoratet, 2012), further calling for teachers' PDC to be definitively described.

Contemporary PDC research examines the concept itself (Johannesen et al., 2014; Krumsvik, 2014; Lund et al., 2014; Mishra & Koehler, 2006a, 2006b; Ottestad et al., 2014) and presents models to describe the nature of such competencies for teaching with technology (Colomer-Rubio et al., 2019; Kelentrić et al., 2017; Mishra & Koehler, 2006b; Pareto & Willermark, 2018; Puentedura, 2006; Redecker, 2017; Aagaard & Lund, 2020). Van Laar et al (2017) described digital competencies for the 21st century, arguing that the 21st-century competencies are not necessarily underpinned by ICT, while on the contrary, digital competencies provide such integration. In combining models for digital competence and models for 21st-century competencies, they conclude with a broad understanding of digital competencies. Applied to the TE context, a broad understanding of PDC encompasses the competencies 21st-century teachers must have to facilitate students' learning. Johannesen et al. (2014) argued that teachers' PDCs have long been interpreted as skills needed to teach *with* digital technology only. Consequently, teaching *about* the technology – how technology works, how to enact digital awareness and how to develop digital tools – as well as teaching *of* technology – how to use particular tools, how to navigate safely in a digital society – have been neglected both in primary and secondary school and TE curriculums. In line with the arguments of Johannesen et al. (2014), this study employs such a broad understanding of student teachers' PDC. In this article we, therefore, employ the concepts of teaching *of*, *with* and *about* technology to discuss how multidisciplinary activities implemented within TE curriculums develop student teachers' PDC.

Methodology

This study adopts a descriptive case study design (Yin, 2003) to examine naturally occurring and interview data to investigate the role played by multidisciplinary activities in a TE programme in developing student teachers' PDC. Understanding the context of a programme requires delving into its history (Patton, 2002). The case under investigation is contextualised to the 20-year history of implementing PDC in a TE programme in the Norwegian context, namely, the OsloMet TE programme.

Norwegian TE programmes educate teachers for kindergarten, primary, secondary, and vocational education, historically located as state-driven TE colleges all over the country, gradually organised as parts of university colleges and universities (Garm & Karlsen, 2004; Munthe & Rogne, 2016). In 2010, a reform divided the TE into two levels: 1st to 7th grade and 5th to 10th grade. The lower-grade TE emphasising the initial training and the higher-grade TE emphasising the subject areas (Ministry of Education and Research, 2010). From 2017 the Norwegian TE is a 5 years master's programme.

In this study, we investigate the TE programme at OsloMet, the largest TE in the country, enrolling approximately 350 primary and secondary school student teachers every year. The teaching is mainly organized in subject areas in addition to the subject of pedagogy.

The data are presented within a sociomaterial perspective (Fenwick et al., 2011; Johannesen, 2013; Orlikowski & Scott, 2008), illustrating both social and material actants, acknowledging that everything, including education, can be understood as effects of hybrid networks of social and material actors (Fenwick et al., 2011; Fenwick & Landri, 2012; Sørensen, 2009). Naturally occurring data, in terms of texts, are recorded without the intervention of a researcher (Silverman, 2006). In this study, such texts are identified as material structures left behind in the process of developing and evaluating a TE programme, in terms of curriculum plans, schedules, reports and personal notes. Peräkylä (2005, p. 869) argued that in this kind of research, the empirical material itself constitutes specimens of the research topic. However, such materials are not transparent representations of organisational routines. They represent ‘social facts’ produced, shared and used in a socially organised way (Silverman, 2006). In this study we treat them as such and investigate the role of these material structures in their interplay with social actors, such as teacher educators and student teachers, to analyse their effects on developing student teachers’ PDC.

However, we cannot learn how an organisation operates from documents alone. Through conversations, researchers can gain insight into past experiences from those involved (Peräkylä, 2005). Informal interviews allow informants to express their thoughts under conditions much closer to ‘naturally occurring’ than conditions in interview settings. Therefore, to further illuminate our research topic, we conducted informal ad-hoc conversations and unstructured interviews (Kvale, 1996) with 4 academic staff who were involved in curriculum development during the two decades under investigation (see table 1). These conversations aimed at clarifying and confirming what is found in the written documents. As part of the teacher educator network, we, as researchers, are among the actors in this case history and might also confirm and question the narrative given by the documented material structures. Consequently, our investigation into the case encompassed clarifying questions and recollection of collective memories about the matter; therefore, this study may, to a certain extent, be considered an autoethnographic study and a reflexive personal narrative (Denzin & Lincoln, 2005, p. 645).

Table 1. Interviewees, their background, experience and responsibility at OsloMet

Interviewee	Holding a master’s degree in:	No. of years at OsloMet TE	Responsibility
#1	Sociology	20	Head of Department of primary and secondary Teacher Education
#2	Informatics	23	Associate professor, senior teacher educator at DDC
#3	Vocational pedagogy	10	Responsible for PDC in TE 5 th to 10 th grade, teacher educator at DDC
#4	ICT-based learning	5	Responsible for PDC in TE 1 st to 7 th grade, teacher educator at DDC

The rich amount of data that texts and interviews produced is challenging to analyse. Peräkylä (2005) argued that the analysis of research-based written text material does not necessarily follow any predefined protocol. Often an informal approach may be best. We organised our material for this study chronologically and observed documented material structures that emerged, such as curriculum plans, teaching plans, multidisciplinary project periods and subject area collaboration. It is particularly interesting to understand how different

material structures shaped practices and vice versa during different periods presented in this case. To do so, we employed the theoretical concepts presented previously to achieve what Silverman described as 'deep analysis of a small set of publicly sharable data' (Silverman, 2006, p. 194).

Findings and discussion

The case study is written from the perspective of the OsloMet Department of Digital Competence (DDC), acting as a 'node' in the multidisciplinary network of educating student teachers, with a focus on PDC. The data material is presented and discussed in three periods determined by the following Norwegian teacher education national curriculum plans: 1) National Curriculum for Teacher Education - 1998 (Ministry of Education Research and Church Affairs, 1999); 2) National Curriculum for Teacher Education – 2003 (Ministry of Education and Research, 2003a) and 3) National Curriculum Regulations for Teacher Education Programmes - 2010 (Ministry of Education and Research, 2010).

First period (1997 – 2002)

The 1997 national primary and secondary education curriculum (L97) (Ministry of Education Research and Church Affairs, 1996) introduced digital technology integral to all school subjects, identifying goals for the use of digital technology at all educational levels and in most subject areas. Many schools established computer labs and arranged for organised digital tool usage training.

To develop student teachers' PDC, a curriculum comprising two elective courses, 'ICT for teachers' were offered for the OsloMet TE programme from 1996 until 2005. In addition, all student teachers at OsloMet were offered basic training in PDC from 1997. This training approach called *broad implementation*, or the *Oslo model* (Bjarnø, 2008), was unique in Norway at the time. The broad implementation was made compulsory in 1998 (Johannesen, 2003). According to Johannesen, the training mostly addressed office support systems and lesson planning, and to a lesser degree, integrating technology into teaching practices.

In 2000 the multidisciplinary project '*Fleirfagleg*' was established at OsloMet: multidisciplinary coursework involving PDC was developed as a new approach to integrating ICT into TE training (Johannesen, 2003). In the *Fleirfagleg* project, coursework assignments were introduced as a method for implementing PDC within a multidisciplinary context (Bjarnø & Sandtrø, 2005). Bjarnø (2005) stated that teaching during this period was most successful when a tight relationship existed between subject areas and DDC teachers. Nevertheless, the student teachers did not regard the PDC training as part of their subject areas. In everyday practical teaching, multidisciplinary might be regarded as conflicting with an organisation that is strongly single disciplinary. This is in line with Hugill and Smith (2013), who argued that co-operation between disciplines, such as a transdisciplinarity approach, paradoxically requires strong disciplines if it is to be meaningful. Therefore, the material structure of coordinated annual schedules and coursework assignments was crucial for implementing multidisciplinary activities and a significant arena for *teaching with technology*.

The *Fleirfagleg* project was also significant in implementing a new Learning Management System (LMS) in OsloMet TE. All teacher educators were trained on the system, the use of which was mandatory in all courses, as all announcements, time schedules and coursework assignments were distributed via the LMS. Making the LMS mandatory was important to developing PDC among teacher educators and was later identified as a significant material structure for strengthening the integration of digital tools and PDC into all aspects of the OsloMet TE programme (Bjarnø & Sandtrø, 2005; Bjørke & Bjarnø, 2004).

Multidisciplinary activities around 2002

Around 2002, several multidisciplinary activities were implemented in OsloMet's TE programme (Bjarnø et al., 2011): first, the same topic was taught in different subject areas simultaneously; second, staff from different subject areas worked together in certain periods, for instance, with cases, tasks and exams; and third, schedules were coordinated so student teachers experienced a diversity of teaching and assessment methods. Throughout this multidisciplinary collaboration, digital technology and the annual coordinated schedule provided the communicative glue. A common core curriculum for the first study year was introduced during this period.

The collaborative activities *basic literacy* and *picture book* illustrated the two first explicitly multidisciplinary arrangements. Basic literacy training was arranged as a multidisciplinary co-operation between the Norwegian language, mathematics, pedagogy and PDC subject areas (Bjarnø et al., 2011). The activities were based on the idea that commonalities in reading, writing and numeracy training were essential for student teachers to understand. To support the multidisciplinary activities, digital tools for basic literacy skills were introduced, used and evaluated by student teachers.

Within *basic literacy*, a core reading list, agreed upon by all parties, was established. In addition, activities that typically would be arranged for in each subject were organised as common activities, illustrating the relationships between the involved subject areas (Interviewee #1). The digital component was not related to PDC per se, but to using digital material, such as 'play and learn' software for basic literacy training. The PDC subject area worked as a glue for the other subject areas. In that way, the digital components provided new and creative ways to organise the multidisciplinary activities and contributed to a mutual inspiration between subject areas (Johannesen, 2003). This corresponds with Hugill and Smith (2013), who argued that digital creativity exists within and across disciplines and that transdisciplinarity leads directly and clearly to digital creativity and vice versa. In addition, student teachers were exposed to *teaching with technology* only.

Another example was the *picture book*. According to Interviewees #1 and #2, the Norwegian language and PDC subject areas transformed this traditionally paper-based coursework into a digital format, aiming to develop student teachers' PDC and their knowledge about multimodal texts. In this setting, the *training of student teachers in technology* worked as a foundation for learning about *teaching with technology* in a multidisciplinary and interdisciplinary context. This new activity was determined to be robust. Although both curriculum and technologies have changed several times, this activity remains an ongoing multidisciplinary activity in OsloMet TE (Interviewee #4).

In summary, the sources referred to in this period (Bjarnø, 2005, 2008; IKT-utvalget ved avd. LUI, 2009; Johannesen, 2003) presented ongoing challenges to developing student teachers' PDC. Nearly without reference to changing PDC training arrangements, the student teachers perceived the training as additional and outside the teaching of subject areas in the TE programme, even though it was incorporated into multidisciplinary coursework assignments (IKT-utvalget ved avd. LUI, 2009). The PDC training was not effectively followed up on by the subject area professionals, who did not regard it as their responsibility. Also, even though there should have been a focus on PDC in practicum, neither student teachers nor practice teachers experienced such.

Emergent multidisciplinary

In this period a dual-mode of delivering elective ICT courses and mandatory integrated PDC training was operative. In the large group lectures, training on using technology was regarded as both too easy and too difficult by different student-teacher groups, reflecting the variation in levels of competence among student teachers. In this early period of training student teachers for PDC, we conclude that much of the training was oriented towards the *teaching of technology*. This is confirmed by the critique raised by student teachers who experienced a weak relation between PDC training and subject areas. Thus, we conclude that the way training was organised did not sufficiently address the multidisciplinary nature of TE and, therefore, lacked the perspective of *teaching with technology*.

In addition, implementing the LMS and making it mandatory in all courses enrolled teacher educators into digital practice for planning and using technology, such as communicating with student teachers and making digital lesson plans. As such, usage of the LMS worked as *teaching with technology* for teacher educators, who subsequently functioned as role models for student teachers. However, having a dedicated DDC delivering PDC training might also have served as an excuse for academic staff from other departments to be involved.

To summarise, this period of PDC training began as a single disciplinary activity of *teaching of specific technology* and gradually evolved into multidisciplinary activities of *teaching with technology*, all orchestrated by the DDC within the multidisciplinary context of the *Fleirfagleg* project.

Second period (2003 – 2009)

The governmental strategy 'Program for Digital Competence 2004-2008' (Ministry of Education and Research, 2003b), which envisioned 'digital competence for all', influenced digital competence policies for years to come. The program presented the first official definition of digital competence as building 'bridges between skills like being able to read, write and do arithmetic and the competence required for using new digital tools and media in a creative and critical way' (p. 7). Access and quality of infrastructure, digital competence and pedagogical use of ICT were emphasised.

The continuous process of integrating PDC as multidisciplinary subject activities into the bachelor level of OsloMet TE engaged many teacher educators; hence, they asked for more coherent and unified learning material. A textbook was produced by four members of the DDC (Bjarnø et al., 2008) and was introduced as core curriculum literature for all student teachers.

An important idea was to present general knowledge that can be useful over time, regardless of changing technologies. The textbook lends itself to many of the multidisciplinary cases developed as parts of the *Fleirfagleg* project. In this way, the textbook itself represents a multidisciplinary approach with a focus on *teaching with* technology. Furthermore, the book included themes that addressed *teaching of* and *teaching about technology*: the first part addresses how to teach with technology, the second part addresses core PDC skills and the third part addresses using technology in teaching and learning. In that way, the textbook itself is a significant material structure that focuses on the *teaching of, with and about technology*, paradoxically represented in the medieval format of text on paper.

A national evaluation report (NOKUT, 2006) identified a lack of focus on ICT in Norwegian TE programmes. In contrast, the report showed that OsloMet TE had succeeded in integrating PDC into curriculum plans, implementing an LMS and addressing the use of ICT in practicum (p. 145). This is confirmed in the national evaluation of PDC in TE programmes (Hetland & Solum, 2008), which identified significant shortcomings in the use of ICT in TE in general, whereas OsloMet TE was honoured for its related work (Tømte et al., 2013).

In 2006 a new national curriculum for primary and lower secondary schools (LK06) was also introduced (Ministry of Education Research and Church Affairs, 2006). In this plan, the use of digital tools and the integration of ICT in all subject areas were further developed. Digital skills were presented as one of five basic skills to be integrated into all subject areas. Basic numeracy, reading, writing and oral skills were easily adopted into math and language training. However, the responsibility for integrating digital skills was unidentified (Engen et al., 2009). In this period schools and school districts began making their plans for ICT training for teachers and students, preparing them for integrating digital skills in all subject areas (Interviewee #1). Interestingly enough, at the same time, many schools stopped appointing teachers with digital technology as their specific responsibility and stopped using dedicated computer labs for training. Similar trends were found in TE programmes, where DDCs were closed (Interviewee #2).

According to Engen and colleagues (2009), newly educated teachers from OsloMet TE regarded themselves as digitally competent and competent in the pedagogical use of technology. Nevertheless, they were sceptical of OsloMet's TE programme's role in establishing that competence. However, those who had specifically worked with PDC as integrated into courses in social and natural sciences mentioned those courses as significant to their understanding of the pedagogical use of digital tools in their subjects (Engen et al., 2009, p. 52).

The OsloMet TE ways of integrating PDC into the TE curriculum may have resulted from the multidisciplinary approach implemented via the *Fleirfagleg* project. The coordinated annual schedule for the whole TE programme acted as a material structure representing and illuminating the multidisciplinary dimensions of the programme. The Ballast project revealed that student teachers exposed to a strong integration of PDC showed a better understanding of the pedagogical use of digital tools. This might indicate a relevant competence of *teaching with* technology as also stated by Hugill and Smith (2013), who underlined the importance of strong disciplines for transdisciplinarity to be meaningful. Also, Engen and colleagues (2009) indicated that the elective PDC courses contributed strongly to the knowledge of *teaching of and about technology*.

Multidisciplinary activities around 2009

During this period most of the multidisciplinary activities developed within the *Fleirfagleg* project continued, but also new activities emerged into theme work periods. The aim was to rely on multidisciplinary activities to develop student teachers' professional competence (Bjarnø et al., 2011). However, in 2010 the multidisciplinary activities the DDC was engaged in were characterised by two-sided collaborations between individual subject areas and PDC, such as cooperation with mathematics on using a digital portfolio or cooperation with pedagogy subject matter on using the word processor to create lesson plans (Interviewee #1, Interviewee #2). In addition, theme work, such as starting school, the picture book and diversity in schools, were arranged for, some with PDC elements. At this point, the OsloMet TE programme started to hold transdisciplinary lectures about teachers' professional competence, named *TPC lectures*, addressing such PDC topics as digital citizenship and academic writing (Interviewee #1). These lectures were a new way of organising PDC-related teaching activities.

Materialisation of multidisciplinary

At the end of this period, the *Fleirfagleg* project ended, and the multidisciplinary approach was not as strong as it had been previously; rather, interdisciplinary collaborations between DDC and subject areas dominated the activities. Most activities involving PDC aimed at *teaching with technology* in subject areas. However, some multidisciplinary activities from *Fleirfagleg* survived in the framing of theme work periods and thereby continued the multidisciplinary approach for *teaching with technology*. As discussed above, the textbook and the coordinated annual schedule were significant material structures developed in this period. In addition, a new material structure, the TPC lectures, were introduced as a new activity for teaching overarching teacher professional competencies, allowing for *teaching about technology*, such as cyber ethics.

One might question whether educating student teachers in the use of technology is relevant. The downsizing of departments and computer labs gave some indications that PDC during this period was regarded as a result of the time we live in, with everyone using digital tools all the time. From this perspective, it was easy to accept that the only competence needed among young student teachers was how to *teach with technology*, not how to use it and criticise it.

Third period (2010 – 2020)

The focus on integrating PDC into teacher education programmes was further strengthened in the next decade. A new national curriculum for teacher education was launched in 2010 (Ministry of Education and Research, 2010). The most important change in this reform was transitioning from a common teacher education programme for 1st through 10th grades into two separate programmes (1st to 7th grade and 5th to 10th grade). Elective subject areas were mostly placed in the fourth study year, which provided an important opportunity for student teachers to specialise in PDC. However, due to national regulations on what subjects constituted an approved teaching degree, few students enrolled in these courses (Interviewee #2).

A framework illustrating digital competence was presented in 2017, namely, the Professional Digital Competence, Framework for Teachers (Kelentrić et al., 2017). The framework

comprised seven competence areas and 49 competencies for teachers and has since laid the foundation for much of the discussion of teachers' digital competence in Norway (Daus et al., 2019; Gudmundsdottir & Hatlevik, 2018; Instefjord & Munthe, 2017; Kongsgården & Krumsvik, 2019). However, from a political perspective, school-related subjects such as PDC could not be prioritised in a TE programme that struggled to arrange for sufficient in-depth studies of school subject areas. In that way, the multidisciplinary activities, aiming at *teaching with technology* still stood strong, whereas there was no space for ICT-related themes addressing the *teaching of technology* and *teaching about technology*. As stated by Engen et al. (2009), it is a paradox that whereas digital competence is a basic skill in primary and secondary education and thereby an important subject of TE, there is no dedicated space for developing such competence as an independent subject area, neither in schools nor in TE programmes.

A new national curriculum plan for primary and secondary education was launched in 2020 (LK20) (Utdanningsdirektoratet, 2017). In this plan responsibility for developing digital competence was given to subject areas, such as digital citizenship in the social sciences, technology in the natural sciences, programming and computational thinking in mathematics, while language topics, music and arts and design are expected to further develop computational thinking skills. Partly to address LK20, a new national regulation for teacher education was implemented in 2017 (Forskrift om rammeplan for grunnskolelærerutdanning for trinn 1–7, 2016; Forskrift om rammeplan for grunnskolelærerutdanning for trinn 5–10, 2016), under which the teacher education programme became a five-year master's programme (Utdanningsdirektoratet, 2018). The use of digital tools and resources are addressed in most subject areas, including the practicum, a series of continuous-profession-development courses in programming were offered and a collaborative initiative between the DDC and mathematics and natural sciences on computational thinking was established. In addition, the DDC and social sciences collaborated on using Minecraft as an educational tool (Interviewee #2, Interviewee #3).

Multidisciplinary activities around 2019

Based on national regulations, OsloMet TE implemented a curriculum plan aimed at all student teachers with four transdisciplinary knowledge areas, named 'columns': research and development, PDC, basic literacy and aesthetic competence (OsloMet-GFU, 2017). The goals for the multidisciplinary and transdisciplinary themes were to be documented in separate plans and incorporated into all subject areas of the five-year programme (Gedde-Dahl, 2019).

In OsloMet TE for 1st to 7th grade, most PDC education was related to other subject areas, typically related to coursework or the teaching placement (Interviewee #4). The programme implemented several multidisciplinary activities between the three main subject areas of the first years, namely, mathematics, Norwegian language and pedagogy, such as school starting/basic literacy, assessment and cultural diversity. The initiative to develop such multidisciplinary activities emerged from several participating subject area departments, and PDC training was easily adopted into these activities.

In OsloMet TE for 5th to 10th grade, most PDC training was provided during the first year and was still separated from the other subject areas (Interviewee #3). Multidisciplinary activities were included in the second year, however, where DDC provided training based on requests from subject areas. For example, mathematics addressed the flipped classroom, so

DDC taught video recording and processing. The picture book project that has been around for almost 20 years as a collaborative activity between the Norwegian language and PDC provides an additional example.

Student teachers' PDC was also addressed in transdisciplinary themes, such as academic writing, where text processing, reference techniques and source critique are subjects in an interdisciplinary week. The TPC lectures continued as an important activity for teaching topics such as cyber ethics.

The new concept of overarching knowledge areas (columns) allowed for transdisciplinary themes to be identified and materialised in the whole programme, one of this being PDC. Gradually, new cross-disciplinary activities emerged in the form of interdisciplinary collaboration between two subject areas and transdisciplinary activities, such as TPC lectures. Within the existing 1st through 7th-grade programme, several multidisciplinary activities allow for PDC to easily map into existing arrangements and train for *teaching with technology* (Interviewee #4). However, in the 5th through 10th-grade programme, which is much more disciplinarily divided, it is more challenging to find activities where PDC can 'fit in' (Interviewee #3). Yet, other subject areas have asked for digital-related training themes, which can be characterised as *training of technology* and as a stepping stone for *teaching with technology* in the subject area.

From 2020, student teachers at OsloMet, who attend the elective pedagogy course, can specialise in digital pedagogy (DIGIPED) during the 6th and 8th semesters. These new courses will give student teachers in-depth knowledge of digitalisation, technology-enhanced learning, digital pedagogy and programming, among other topics, and may form the basis for writing a master's thesis within the field of digital pedagogy (Interviewee #2).

Towards transdisciplinarity?

OsloMet TE continued its work integrating PDC into the whole of TE programme. During this period the 2010 teacher education curriculum reform, which aimed at strengthening school subject areas, made it difficult to incorporate PDC independent of subject areas in the TE programme. Consequently, strong two-sided cooperation between subject areas and PDC, and the TPC lectures, constituted the bearing material structures.

The ongoing implementation of the 2017 TE curriculum reform at OsloMet aims at strengthening the material structure of multidisciplinary and transdisciplinary activities in terms of distinct documentation (Gedde-Dahl, 2019) and establishes material structures that can support the transdisciplinary nature of TE. Therefore, several specialists can contribute to a common didactic situation with different questions in mind (Lanciano, 2019). This is also supported by Jarning (2012), who stated that multidisciplinary coordination can be seen as balancing professional and disciplinary knowledge cultures.

Finally, the new elective course DIGIPED allows for in-depth study of digital tools and digital pedagogy, hence arranging for the *teaching of and teaching about* technology, yet also *teaching with technology*. Although a broad implementation has been the ideal of developing PDC, the complexity of TE and competing for space in the national regulated programme does not allow for the in-depth PDC training of all student teachers. Thus, elective courses function as an arena for developing specialists, who, in turn, can contribute to developing PDCs in their professional environments.

As of this writing, computational thinking is the ‘shining star’ in education, addressing one of many transdisciplinary goals of competence for the 21st century. Like most TE programmes, OsloMet offers a variety of such in-service and pre-service courses. While this trend addresses our concern about student teachers’ deficient competencies in *teaching in and teaching about technology*, we question whether computational thinking as a dedicated subject alone can cover the range of digital competencies, beyond teaching with technology, that PDC constitutes.

Summary and conclusion

To summarise the findings of this study, Table 2 presents the core collaborative activities, described in previous sections, followed by the corresponding emerging multi-, inter- and transdisciplinary activities and the analysis of how these activities lay the foundation for student teachers to develop competencies in the teaching of, with and about technology.

Table 2. Summary of multidisciplinary TE activities and their contribution to PDC

Core collaborative TE activities	Emerging multi/inter/transdisciplinarity	Teaching of/with/about technology
2003 Basic literacies Picture book	Emerging awareness of multidisciplinary and implementation of such processes	Teaching <i>of</i> technology, to arrange for teaching <i>with</i> technology in practicum
2009 Basic literacies Theme-work periods TPC lectures	Materialisation of multidisciplinary activities through annual coordinated schedule, core curriculum and textbook Cooperation developed into interdisciplinary activities between two (three) subject areas. Emerging transdisciplinary activities, such as TPC lectures	Teaching <i>of</i> specific PDC-related themes, aiming at educating student teachers to teach <i>with</i> technology TPC lectures bring about awareness on such topics as cyber-ethics, i.e. teaching <i>about</i> technology
2018/19 Transdisciplinary themes TPC lectures Theme work periods DIGIPED Programming	Materialisation of transdisciplinary activities in ‘columns’ Interdisciplinary cooperation between DDC and the subject area of pedagogy on DIGIPED	Columns: Targeted teaching <i>of</i> specific technology-related themes, aiming at educating student teachers to teach <i>with</i> technology Theme work without specific focus on PDC The DIGIPED course and programming arrange for teaching <i>of</i> and <i>about</i> technology

In this article, we conclude that student teachers’ PDC benefits from being part of a multidisciplinary approach. As illustrated in table 2, the PDC training at OsloMet has developed from being an independent subject area of former TE programmes to a fully integrated structure, showing that multi-, inter- and transdisciplinary framings can contribute to fulfilling the goals of educating student teachers for teaching with technology. However, other aspects of teachers’ PDC, such as being able to teach about the implications of technology use or explain how

technology functions, were addressed to a lesser degree and need to be incorporated into subject-specific learning activities.

The case of OsloMet TE showed that national curriculum plans and regulations strongly influence how TE programmes implement such training. However, locally implemented material structures are also crucial in negotiating what ways and to what extent activities addressing PDC can be a part of the TE programme. The importance of material structures, in particular the sociomaterial effect of such in education, are previously identified in educational research, such as Sørensen (2009) in her study of a 3D-virtual environment in a fourth-grade class and Fenwick and colleagues' publications on sociomaterial approaches in education research (Fenwick & Edwards, 2010, 2012; Fenwick et al., 2011; Fenwick & Landri, 2012). These material structures might be coordinated into multi- inter- and transdisciplinary activities, such as reading lists, annual schedules, textbook and coursework assignments. The three main periods identified in this study can be characterised in terms of a boomerang, bringing us back to the point of departure. In the first period, the focus on PDC was materialised in terms of a curriculum for elective courses, DDCs in TE programmes, computer labs, and ICT responsible teachers in schools. All elements of *teaching of, with and about technology* were presented in lecture format. The second period was characterised by the mantra of *teaching with technology*. Digital competence was introduced as one of five basic skills and found its natural place within all subject areas in schools. This might be the reason for educational actors believing that downsizing ICT departments and closing computer labs at both schools and TE programmes as appropriate. The last period is characterised by a new focus on specialisation, such as elective courses in digital pedagogy and programming, yet also emerging material structures for new transdisciplinary activities. Although this period is in its early framing, we can see that elements of the *teaching of, with and about technology* have been given better conditions and a corresponding capacity to develop all elements of student teachers' PDC.

The case of OsloMet TE shows that developing student teachers' PDC has involved a series of innovations, guided by forthcoming and implemented national regulations, practical experiences, material structures, national evaluations and a strong DDC. These are: 1) the broad implementation where all student teachers should be trained in PDC, 2) the project *Fleirfagleg*; introducing multidisciplinary coursework with a PDC content, 3) the compulsory use of LMS for all teacher educators, 4) the theme work periods involving the use of digital tools, such as the picture book, 5) the textbook on PDC relevant to all subject areas of the TE programme 6) the TPC lectures addressing topics specific for PDC 7) the organising the TE-programme into transdisciplinary knowledge areas (columns) and finally 8) the offering of elective PDC courses DIGIPED as a specialisation in the TE programme. Whereas a national report (NOKUT, 2006) indicated the success of individual measures for implementing PDC at OsloMet, the integration of PDC at OsloMet might as well be a result of a well-orchestrated sociomaterial system of multi-, inter- or transdisciplinary activities, which, in turn, support the development of student teachers' competencies in the *teaching of, with and about technology*.

By employing a sociomaterial perspective in describing and analysing the PDC-training implementation, this case description might have revealed overlooked educational processes which otherwise would have remained invisible. In that way, this study illustrates that a sociomaterial approach in educational research "can reveal materialist dynamics of oppression, exclusion and agonism that are in play" (Fenwick et al., 2011, p. 15).

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