



Research paper

Evaluating the impact of a digital competency-based placement model on STEM pre-service teachers' digital competence and teaching experiences

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ABSTRACT

This study examines the impact of the Digital Leader Placement Programme (DLPP), a digital competency-based placement model, on STEM secondary level pre-service teachers' (PSTs) digital competence and teaching experiences. Grounded in the ICT-TPACK Science Framework, digital competence is explored as a multidimensional construct encompassing pedagogical, ethical, and technical dimensions. A mixed-methods evaluative case study was conducted with two PST cohorts (N = 52), using pre/post-programme questionnaires and focus groups. Results show significant gains in planning, designing, implementing, and technical proficiency, though ethical competence improved less. Focus groups revealed themes such as disparities in school technology access, difficulty integrating digital literacy, and growing ethical awareness. The study highlights the value of low-stakes, reflective placements in developing digital competence and identifies systemic barriers, including the digital divide and inconsistent institutional support. While the DLPP shows promise for embedding digital skills in teacher education, further research is needed to assess its long-term impact and scalability.

1. Introduction

Advances in digital technology continue to influence educational systems globally, generating both enthusiasm and critical debate regarding their role, impact, and implications for teaching and learning (UNESCO, 2023). Educational policymakers worldwide increasingly prioritise concepts such as digital literacy and digital citizenship, integrating them into national curricula and strategic education frameworks. Frameworks such as the UNESCO ICT Competency Framework for Teachers (UNESCO, 2018) and the European Framework for the Digital Competence of Educators (DigCompEdu) (Punie, 2017) exemplify international efforts to guide educators toward integrating digital technologies into pedagogical practice. The policy orientation of these frameworks reflects a broader sociocultural shift towards embedding digital skills as foundational competencies in contemporary educational systems. Within this global policy context, this paper is concerned specifically with secondary-level education, focusing on the preparation and professional formation of secondary level teachers and the implications of digital policy for their pedagogical and ethical practice.

In Ireland, these global trends are clearly reflected in recent national

educational policies, notably the Department of Education's Digital Strategy for Schools (2022), which explicitly underscores digital literacy as critical for learners and highlights the essential role of teachers in facilitating its development. Consequently, there has been significant pressure on Initial Teacher Education (ITE) programmes, particularly those preparing teachers for secondary education, to align with this evolving policy context. The Teaching Council of Ireland, responsible for accrediting ITE programmes, has responded by explicitly integrating digital skills as a core element within the accreditation framework under the Céim standards. These standards define digital skills broadly to include digital literacy, the effective use of digital technologies in teaching, learning, and assessment, and opportunities to explore emerging technologies (The Teaching Council, 2020).

While recent policy developments reflect optimism about the role of digital technology in education, critical scholarship highlights significant concerns and ethical challenges. These include a variety of concerns associated with, inter alia, the ongoing encroachment of 'big data' and machine learning in education (Knox et al., 2020), the continuing reach of the psy-complex within contemporary policy (Gillborn & Delahunty, 2025), the evolution of technologies of governance as part of the

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futures-oriented politics (Yliniva et al., 2024). Recent critiques have also drawn attention to the dubious technosolutionist 'ethical' framing in intergovernmental policy on AI in education (Mochizuki et al., 2025), highlighting how intergovernmental organisations can reinforce dominant political and economic agendas.

Ethical concerns, such as the implications of datafication, surveillance, and privacy in educational contexts demand critical examination (Delahunty, 2024a; Williamson, 2021; Selwyn, 2019) as do issues such as platformisation, where education becomes increasingly mediated by privately owned digital platforms, potentially eroding teachers' autonomy and exacerbating educational inequalities (Perrotta & Pangrazio, 2023). Issues around commercialisation further underscore concerns that educational priorities may become secondary to profit-driven interests (Johnston & McGarr, 2022). Collectively, these highlight how the neoliberal governance of education intersects with technological integration, where education becomes increasingly influenced by private technology companies (Ball and Grimaldi, 2022).

These critiques highlight the need for ITE programmes to equip teachers with not only pedagogical proficiency but also an ethical understanding of the implications of digital technologies within broader educational and global landscapes. Indeed, the very nature of approaching and conceptualising the use of digital technologies in education has been described as entangled in complex sociocultural contexts, not just by methods and the technology itself, but also by the purposes, contexts and values of teachers, students, and other stakeholders (Fawns, 2022).

While the potential of digital technologies to enhance educational practice and outcomes does exist, it is contingent on strong pedagogical alignment and critical engagement from teachers themselves (Castaño Muñoz et al., 2021; Cabero-Almenara et al., 2022). Technology's positive educational outcomes are contingent upon robust teacher input and pedagogical alignment (Christensen & Trevisan, 2023; UNESCO, 2023; Wekerle et al., 2020). This perspective emphasizes the need for critical, balanced approaches to technology integration within ITE programmes, encouraging prospective teachers to adopt technology thoughtfully, reflecting not only technological possibilities, but also critical awareness of their limitations.

Acknowledging the potential of technology in education alongside its ever-increasing role in data-intensive precision governance (Williamson, 2021), concomitant to the intensification of neoliberal ideology and scientism in educational policy (Delahunty, 2024b), sketches a complex pedagogical landscape for ITE. Consequently, the focus on promoting a holistic set of skills in digital education among teachers is and should be integral to any policy initiatives in this space. While there is a need to ensure that students develop their digital literacy skills to thrive in an ever more globally connected world (Romero-García et al., 2020), a balanced approach is essential and must be predicated on an appropriate conceptualisation of teachers' digital competence.

1.1. Conceptualising teacher digital competence

For the purposes of this study, several key terms are defined as follows. Digital competence is understood as the integrated capacity to use digital technologies in effective, critical and ethically responsible ways for learning, teaching and participation in society. In the context of teachers, this encompasses the pedagogical, technological, ethical and professional dimensions of practice (Kadioğlu-Akbulut et al., 2020; McDonagh et al., 2021; UNESCO, 2018), while for learners it refers to the development of critical, creative, and responsible digital engagement as articulated in policy frameworks such as DigCompEdu (Punie, 2017). Digital literacy is conceptualised as the ability to critically access, evaluate, create and communicate information using digital technologies in socially and educationally responsible ways (Pangrazio et al., 2020). Digital citizenship is understood as the ethical, responsible, and participatory engagement with digital technologies, including issues of

online safety, data privacy, civic participation and social responsibility (Chen et al., 2021). Finally, digital technology in education is conceptualised not merely as a set of tools, but as a sociotechnical system that shapes pedagogical practice, professional identity, governance and educational values (Fawns, 2022; Selwyn, 2010).

While these definitions provide a foundational understanding of key concepts, it is also necessary to clarify the broader vision of technology in education that underpins this research. In conceptualising teachers' digital competence, technology in education is understood not merely as an instrumental or utilitarian tool for enhancing instructional efficiency, but rather as a transformative medium with significant implications for pedagogy, professional identity, ethics and social justice. Aligning with an ethical-pedagogical position, technology integration in educational contexts is viewed through a lens that acknowledges both its potential to facilitate meaningful, inclusive and empowering learning experiences, and its capacity to perpetuate inequalities or reduce teacher autonomy when inadequately conceptualised or uncritically implemented (Selwyn, 2010).

McGarr and Johnston (2021) describe varying roles technology can occupy in education through policy that can be underpinned by four principal rationales: educational, economic/vocational, social, and catalytic. These rationales highlight the need for a comprehensive awareness of the broader implications and motivations behind the use of digital technologies in education. Thus, there is a need to situate it in these broader contexts while also ensuring not to reduce it to merely a tool for knowledge acquisition, but a mechanism for enabling worthwhile social experiences that foster connection (Biesta, 2010; Bray et al., 2021). Such an approach reflects pedagogical maturity, recognizing that successful technology integration is contingent not merely upon infrastructure provision or economic outcomes, but on a nuanced understanding of education as fundamentally relational, complex, and contextually embedded (McGarr & Johnston, 2021). This perspective integrates these rationales within a broader vision that aligns technological advancement with educational aims grounded in social affordances, reflective practice, and human agency.

Reflecting this theoretical stance necessitates an exploration of frameworks that extend beyond narrow technical skills towards models encompassing ethical, professional, and critical pedagogical competencies. In this study, the ICT-TPACK Science Framework (Kadioğlu-Akbulut et al., 2020) is adopted as the guiding conceptual model for examining teacher digital competence within STEM education. Building on Mishra and Koehler's (2006) foundational Technological Pedagogical Content Knowledge (TPACK) framework, the ICT-TPACK Science Framework is explicitly tailored to address the unique requirements of science educators. This extended framework integrates five interactive dimensions: planning, designing, implementing, proficiency, and ethics with the original TPACK interconnected domains of technological, pedagogical, and content knowledge. By incorporating these dimensions within a subject-specific framework, the ICT-TPACK Science Framework provides a comprehensive, discipline-focused lens for examining teacher digital competence, closely aligning with the pedagogical and ethical concerns central to science education.

The selection of ICT-TPACK Science is informed by the broader theoretical landscape of teacher digital competence frameworks. The original TPACK framework (Mishra & Koehler, 2006) emphasizes the integrated nature of effective teaching through the intersection of technological, pedagogical, and subject-specific content knowledge. This model underscores that teacher effectiveness in digital environments depends upon strategically combining these domains to enhance learning outcomes. However, a key limitation of TPACK is its lack of explicit consideration for ethical knowledge (Deng & Zhang, 2023), a gap that later frameworks have sought to address.

One such extension is the Teacher Digital Competence (TDC) framework developed by Falloon (2020) which explicitly incorporates personal-ethical and personal-professional domains alongside the

TPACK knowledge base. These additional dimensions address cyber ethics, digital citizenship, professional learning, and ethical responsibility concerning digital technology's broader social and environmental impacts. While the TDC framework provides greater specificity through detailed descriptors, potentially offering clearer guidance for implementation and assessment, this level of specification may also constrain teacher agency.

Similarly, the Pedagogical, Ethical, Attitudinal and Technical (PEAT) Model (McDonagh et al., 2021) proposes a more holistic and flexible conceptualisation of teacher digital competence, structured around pedagogical, ethical, attitudinal, and technical dimensions. Its explicit inclusion of ethics represents a critical advancement, emphasizing the necessity for educators to engage critically with the sociocultural implications of technology use. The PEAT model aligns closely with the critical stance outlined above by affording greater scope for professional autonomy and contextual interpretation, thus supporting teachers as active agents rather than passive implementers of technology policy.

At a broader level, the European DigCompEdu framework (Punie, 2017) is notable for offering a comprehensive structure, addressing teachers' pedagogical and professional competencies, alongside explicitly acknowledging their role in fostering learners' digital competences. However, despite its breadth, DigCompEdu has drawn criticism, particularly for contributing to an overly prescriptive and performative approach to teacher competence, potentially compromising teacher autonomy and agency (McGarr, 2019).

Collectively, these frameworks illustrate that while TPACK remains a consistent point of reference across the field, many contemporary frameworks and assessment instruments are either directly derived from or conceptually influenced by TPACK (Falloon, 2020; Karlsen et al., 2025) underscoring its foundational role in shaping understandings of technology integration in education. However, there is growing recognition that digital competence is highly context-specific, shaped by subject area, educational setting, and disciplinary demands (Saubern et al., 2020; Wang et al., 2018). In light of this, a subject-specific conceptual model, the ICT-TPACK Science Framework was selected to support a more nuanced investigation aligned with the needs of STEM education. This contextual sensitivity also has important implications for how digital competence frameworks are implemented within teacher education, an issue explored in the following section.

1.2. Development of digital competence in teacher education programmes

While reforms such as the Digital Strategy for Schools (Department of Education, 2022) and the Céim Standards for ITE (The Teaching Council, 2020) signal progress towards acknowledging digital technology's educational potential, concerns persist regarding how they are influenced by predominantly techno-positivistic discourse and insufficient attention to pedagogical and ethical dimensions (McGarr, 2024; Wallace et al., 2023). However, despite these ambitious policy frameworks, research highlights persistent implementation challenges due to inadequate resourcing, inconsistent teacher professional development opportunities, and a lack of systematic integration of digital technologies within existing curricular structures (Scully et al., 2021). Considering national and international priorities advocating for the development of teacher competence in initial teacher education programmes and the complex nature of the landscape involving multiple stakeholders, there is a need to consider thoughtful and novel approaches to developing teacher digital competence.

Studies focusing specifically on STEM contexts demonstrate that digital competence development among both pre-service and in-service teachers is strongest when technology integration is embedded within authentic, subject-specific practice. Research with pre-service science and mathematics teachers shows that structured TPACK-informed interventions improve confidence, instructional design and classroom implementation, particularly when supported through makerspaces, ICT-integrated pedagogy, and targeted STEM coursework (Baran et al.,

2019; Max et al., 2023; Samantray et al., 2024). However, as previously suggested, studies with in-service STEM teachers highlight persistent barriers to sustained integration, including curricular overload, uneven access to resources, and limited professional learning time, despite gains in TPACK and pedagogical confidence through professional development programmes (Mansour et al., 2024; Wahono et al., 2025).

The literature suggests that the development of teacher digital competence has to extend beyond just learning about technology and should include active approaches that provide both teachers and pre-service teachers (PSTs) with guided opportunities to consider different types of digital technology and how they can be implemented within the classroom (Gabarda Méndez et al., 2023; Miguel-Revilla et al., 2020). Adopting educational strategies that place an emphasis on reflective practice can also be beneficial in the context of improving teacher digital competence, and examining the relationships and interactions between technological, pedagogical, and content knowledge (Baran et al., 2019). While studies propose various alternatives for integrating technology into education, there is still scope for further expansion beyond methods and the technology itself by creating a space for exploration and critique of the broader sociocultural landscape (Fawns, 2022; McGarr, 2023; Wallace et al., 2023).

While much can be achieved in developing teacher digital competence and attitudinal disposition towards digital technologies in the classrooms of third level institutions (Pongsakdi et al., 2021; McGarr, 2023; Haşlamani et al., 2024), school placement provides PSTs with vital experiential and formative opportunities to put their knowledge and skills into practice (Bastian et al., 2020). However, the high-stakes nature typically associated with placement by PSTs, arising from its assessment, can present a challenge (McGarr, 2021). Thus, there is scope to explore a low-stakes model which would allow PSTs to develop their digital competence, experiment in practice and afford opportunities to reflect on the broader landscape without necessarily needing to worry about the grades. Given this need for a low-stakes approach to placement, the Digital Leader Placement Programme (DLPP) was conceived as a context that could support PSTs in developing digital competence while mitigating the pressures typically associated with traditional high-stakes placements.

2. Current research context: the Digital Leader Placement Programme (DLPP)

The design and implementation of our digital competency-based placement programme took place within a challenging and evolving teacher education landscape. As a team, we faced persistent difficulties in securing suitable placements in schools. These challenges were further exacerbated by ongoing curricular reform, uneven technological infrastructure across schools, and the broader impact of economic inflation, which affected students' ability to afford transport and housing during placement. Compounding these issues was a lack of guidance within Céim on how to meaningfully embed a digital focus in teacher education, a gap that, while offering some flexibility, required the team to develop a framework from the ground up.

The DLPP was developed as an introductory placement for second year undergraduate secondary level PSTs, specialising in STEM. The programme itself is situated in the second semester of a yearlong module, where the first semester focuses on peer teaching, observation and reflective practice. It involved a partnership with an industry partner wherein students would engage in a series of workshops followed by placement in partner schools to deliver STEAM (Science, Technology, Engineering, Art and Math) lessons utilising a range of 'unplugged' activities (learning experiences that teach concepts such as coding or computational thinking without using digital devices or technology) alongside using digital devices such as Micro: bit and Sphero. This partnership afforded access to the partner schools, expertise in digital technologies and a scheme through which our students could borrow suitable devices from an industry partner.

At the time of participation, Year 2 PSTs were in the early stages of their Initial Teacher Education programme. Prior to the DLPP, they had completed foundational coursework focused on pedagogy and learning theory. They had not yet undertaken extended placements. While digital tools were occasionally used within coursework for communication or assessment purposes, there was no prior structured module explicitly focused on digital pedagogy, technology integration or ethical dimensions of digital education.

Prior to going on placement, students attended three 3-hour digital education workshops alongside three 3-hour workshops led by our industry partner over the course of three weeks. Each series of workshops had varied but complimenting focus. The digital education workshops were led by a member of the academic team and focused on areas such as planning, implementation, pedagogy and ethical considerations, whereas the industry partner workshops were delivered by qualified teachers focused on planning and hands-on activities which the students would then implement in their partner schools. Collectively, the workshops addressed digital competence development through lesson planning, pedagogical decision-making, implementation and assessment, critical engagement with digital tools and ethical considerations related to data, access, and digital literacy, as illustrated in Fig. 1. It is worth noting that our industry-partner adopts a platform-agnostic approach, allowing schools to participate irrespective of the devices or operating systems they use, including but not limited to Google, Apple, and Microsoft platforms. This inclusivity supports broader access to digital learning opportunities. An overall breakdown of the content covered can be seen in Fig. 1.

Following the completion of the workshops, PSTs were then given the opportunity to implement and practice what they had learned over the course of a one day per week placement over eight weeks. Cooperating teachers in placement schools met standard placement requirements but were not selected based on specific digital competence criteria. Their role was primarily supervisory and contextual, facilitating classroom access and supporting PSTs during placement rather than acting as mentors for digital pedagogy. Each day on placement, PSTs were expected to teach two lessons while also engaging in observation of other classes in their placement schools. They would teach students in the first to fourth years of Irish secondary school (approximately ages 12–16). What differentiated this placement from typical placements was the nature of its assessment. Students were not assessed based on their teaching performance in class, rather the assessment was focused on

observation and reflective practice. Over the course of placement, students designed a portfolio of artefacts across a series of four competencies, namely, Planning and Preparation, Teaching, The Learning Environment, and Professional Responsibilities. Students created a written reflection on each of these artefacts which formed the basis of two professional dialogues with placement tutors.

The nature of this assessment meant that the high-stakes nature typically associated with how they performed in the classroom (McGarr, 2021) was reduced, allowing space for students to be creative, experiment and try out new approaches utilising the technologies and techniques derived from the workshops without concern for the impact it would have on their grade. The programme itself represented an attempt at a productive public/private partnership that aimed to improve PSTs' digital competence. It was envisaged that the combination of workshops, alongside a low stakes placement assessment and the opportunity to reflect on their experiences and observations would have a positive impact on teacher digital competence. This programme took place in the early years of the overall academic programme and serves as an introductory element which was then built upon in later stages of the programme.

2.1. Research aims & questions

The study aimed to examine the impact of the DLPP on PSTs' development of digital competence and their teaching experiences. Situated within an understanding of technology in education informed by the ICT-TPACK Science Framework, the research explores digital competence not simply as technical skill, but as encompassing pedagogical and ethical dimensions. The study investigates how participation in the DLPP shapes PSTs' capacity to integrate technology, and how it influences teaching practices and understanding of technology's role in education.

To address these aims, the study was guided by the following research questions.

1. What is the impact of the DLPP on PSTs' self-reported digital competence?
2. How do PSTs experience and navigate the integration of digital technologies in their teaching practices during the DLPP?

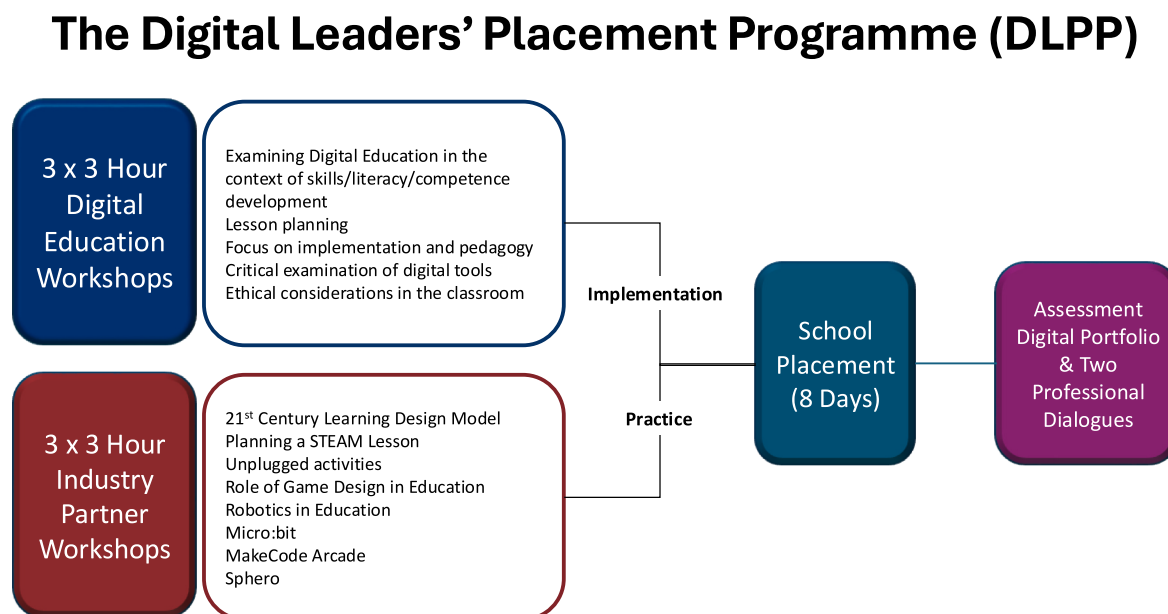


Fig. 1. Structure of the DLPP

3. Method

3.1. Research approach

A multi-stage mixed-method evaluative case study design was adopted to align with the study's aim of exploring the impact of the DLPP on PSTs digital competence and teaching experiences (Yin, 2018). Grounded in an understanding of technology in education, which views digital competence as encompassing pedagogical and ethical dimensions, this approach enables an exploration of both measurable developments in competence and the complex, situated experiences of PSTs integrating technology in classrooms. A mixed-method design was essential to address the research questions, allowing for the triangulation of quantitative and qualitative data to examine not only what changes in competence occur but also how and why these changes take shape within placement contexts.

The case study approach provided a way to explore the DLPP in-depth within its specific institutional and relational contexts, offering insight into both outcomes and processes. The evaluative dimension reflects the study's focus on understanding the programme's impact, while the multi-stage design allowed for the tracing of PSTs' development over time, from initial preparation to enacting digital roles in schools. This design supports a nuanced understanding of how digital competence evolves as part of broader professional learning ensuring alignment between the complex, relational conceptualisation of technology that underpins the study and the methodological approach used to investigate it.

3.2. Participants

The participants for this study were undergraduate PSTs required to undertake school placement as a core requirement of an introductory education module. These students were studying to teach across a range of STEM subjects at post-primary/secondary level. There were two cohorts of students who participated. The first cohort were Year 2 PSTs who completed both a pre (n = 30) and post (n = 25) questionnaire, some of whom also participated in two separate focus groups (n = 7). The second cohort of students were Year 3 PSTs who had completed the DLPP programme in their previous year.

These PSTs completed a post questionnaire to ascertain their level of digital competence (n = 22) and some of these also participated in a focus group (n = 3). As the study was originally designed to be implemented with the Year 2 cohort, a questionnaire was not administered to the Year 3 students pre-intervention, however, post-intervention data were collected to capture their perspectives following completion of the DLPP in the previous year. Participation in the focus groups was based on voluntary self-selection, with students invited to opt in following completion of the questionnaire. As such, the focus group participants may not be fully representative of the wider cohort.

At the programme level, the second-year cohort for the 2022–2023 academic year consisted of 38 students, of whom 27 were female and 11 male. This group included three students of Polish nationality, one Romanian student and one British student, while the remaining students identified as Irish. Ages within the cohort ranged from 18 to 27 years. The third-year cohort included 41 students (28 female and 13 male), with one student identifying as Polish and all others as Irish. Demographic information at the individual participant level was not gathered, as the relatively small cohort sizes raised concerns regarding potential participant identifiability.

3.3. Design

The first phase involved the distribution of a pre-intervention questionnaire to participants prior to engaging with the programme to ascertain their current level of digital competence. The second phase was the implementation of the programme. The third phase involved the

distribution post-intervention questionnaire to ascertain their level of digital competence. The fourth phase involved three focus groups with participants to examine their experiences of the programme in more depth. The final phase of the research involved an analysis of submitted artefacts and reflections which were selected based on varied ranges of digital competence identified from phase three. This paper presents the findings from phases one to four of the programme.

3.3.1. Questionnaire

This study adopted a previously validated instrument to ascertain PSTs level of digital competence. We used an adapted version of the ICT-TPACK Science Scale developed by Kadioğlu-Akbulut et al. (2020). The scale was originally developed to measure pre-service science teachers' TPACK within the context of science education. Grounded in the transformative TPACK model, it focuses on evaluating teachers' ability to integrate ICT in science instruction by considering recent advancements in educational technologies. The scale examines five factors across 38 items which encompass the interaction between the technological, pedagogical and content knowledge domains identified in the TPACK model. These factors and a sample item from each are outlined in Table 1.

The scale was adapted by replacing references to “science” with “STEM” to reflect that participants teach across multiple STEM subject

Table 1
ICT-TPACK science scale factors.

Factors	Number of Items	Description	Sample Item
Planning ICT-Integrated Science Instruction	8	Assesses the ability to plan and select appropriate technologies and methods for science teaching based on students, content, objectives, and resources.	I can determine appropriate instructional technologies and pedagogical approaches by evaluating student characteristics, duration, content, and attainment in the science teaching process.
Designing Materials for ICT-Integrated Science Instruction	6	Evaluates the ability to create or adapt digital materials like videos, simulations, AR, and online assessments for science education.	In the process of STEM teaching, I can create/update online assessment evaluation activities using technologies such as Socrative, Kahoot, Blooket etc. in accordance with the student characteristics, duration, content, and attainment.
Implementing ICT-Integrated Science Instruction	12	Measures the ability to effectively teach using technology, manage classrooms, assess learning, and stay updated on new educational tools.	I can apply instructional approaches and methods appropriate to individual differences in STEM teaching with the help of technology.
Ethics in ICT-Integrated Science Instruction	6	Examines ethical use of technology, focusing on access, privacy, and intellectual property.	I can behave ethically regarding appropriate use of technology in the STEM teaching process.
Proficiency in ICT-Integrated Science Instruction	6	Assesses problem-solving with technology, mentoring others, and collaborating across disciplines in science education.	I can guide my colleagues in using technology to solve the problems encountered in the STEM teaching process.

areas. The adapted instrument was used as an evaluative measure within this specific programme context and was not intended as a formal revalidation for STEM education. To support the appropriateness of this adaptation, three STEM educators reviewed the modified items for clarity, content relevance and alignment with STEM teaching contexts, supporting face and content validity but not full psychometric validation. Internal consistency estimates for both the original and adapted versions of the scale are reported in Table 2 to provide transparency regarding reliability within the current sample.

3.3.2. Focus groups

The focus group interviews took place after the students completed their placement experience. Focus group questions were piloted with two Year 4 PSTs, questions were refined for clarity based on the feedback. The questions were informed by the TPACK-STEM Scale, incorporating dimensions related to planning, teaching, assessment and ethical concerns. They were also derived from the literature on challenges experienced by in-service and pre-service teachers in integrating technology (Deng & Zhang, 2023; Falloon, 2020; Gabarda Méndez et al., 2023).

Following the pilot, a protocol was developed which involved a series of questions across four different sections. The first section involved general information and invited participants to discuss the technological opportunities they had in their schools. The second section focused on the integration of technology into teaching and the participants shared their experiences. There were deliberate questions focused on how they integrated technology into their planning, as well as on the ways they used technology for assessment. The third section focused on support for the integration of technology into teaching. This included questions about the suitability of the curriculum and whether adequate support was provided by the university or the school. The final section addressed the development of students' digital literacy and addressing ethical considerations associated with technology use. Example questions included: *As a science or mathematics teacher, what is your responsibility in fostering students' digital literacy?* and *What ethical issues might arise when using technology in teaching?* Participants were also asked whether these factors would influence their intention to use technology in the classroom.

3.4. Implementation

Data collection took place at the beginning and the end of the spring semester of 2023 and involved a series of stages. The first round which included the pre-questionnaire was collected from both second and third year cohorts in January of 2023. The second round of data collection included the post-questionnaire with the second-year cohort which took place over April to May of 2023. The final round of data collection included the focus groups which took place in April 2023 (third year cohort) and May 2023 (second year cohort). Focus groups were recorded and transcribed.

Table 2
Reliability estimates of the original (Kadıoğlu-Akbulut et al., 2020) & adapted scale.

Factor	Original Cronbach Alpha	Adapted (Current) Cronbach Alpha	95% CI [LL; UL]
Planning	0.88	0.76	[0.73; 0.8]
Designing	0.83	0.86	[0.83; 0.88]
Implementing	0.90	0.85	[0.83; 0.86]
Ethics	0.84	0.92	[0.91; 0.93]
Proficiency	0.88	0.86	[0.84; 0.89]

Note. Note: CI = confidence interval; LL = lower limits of 95% CI; UL = upper limits of 95% CI.

3.5. Analysis

Descriptive and inferential analyses were performed on the quantitative data collected from the questionnaires. A series of paired samples t-tests were conducted to identify if any statistically significant differences existed between groups pre and post intervention. This method allowed us to measure the effect size and determine the magnitude of differences, ensuring a reliable comparison across the variables under study.

The qualitative data from focus groups was thematically analysed according to Braun and Clarke's (2013) six-phase framework. This analysis involved a combined deductive and inductive approach. The deductive approach involved the use of the ICT-TPACK Science Scale factors to identify developments of digital competence while inductively the authors developed themes from the data. This analysis was first carried out by two members of the research team. Following an initial familiarisation with the data, the researchers generated and reviewed initial codes. These were subsequently combined into six initial themes. Following a review of these themes and their associated codes by another researcher on the team, some themes were combined into four refined themes. These were then subsequently reviewed by the full team and accepted for reporting.

3.6. Ethics

Ethical approval was granted by the Social Research Ethics Subcommittee at the host institution. Participation in the study was entirely voluntary. The participants provided their consent to participate prior to completing the questionnaire and engaging in focus groups. To protect the anonymity of the participants, they were not asked to provide any personal information which could be used to identify them.

4. Findings

4.1. ICT-TPACK results

Paired-samples t-tests were conducted to examine whether participation in the DLPP was associated with statistically significant changes in PSTs' self-reported digital competence across the five ICT-TPACK factors. For this analysis of the 25 participants, who completed both the pre/post questionnaires, 4 had to be excluded due to missing values. Prior to analysis, the normality assumption for the paired differences was assessed using Shapiro-Wilk tests and visual inspection of Q-Q plots. All factors met the normality assumption (all p values > 0.05). The assumptions for the paired-samples t-tests were therefore satisfied.

Significant improvements were observed in participants' scores for Planning, $t(20) = -3.45, p = .003, g = -0.73, 95\% \text{ CI } [-1.20, -0.26]$, reflecting a medium effect size. For Designing, there was also a significant increase, $t(20) = -3.12, p = .005, g = -0.66, 95\% \text{ CI } [-1.12, -0.20]$, indicating a medium effect. Similarly, Implementing showed significant gains, $t(20) = -3.16, p = .005, g = -0.67, 95\% \text{ CI } [-1.13, -0.20]$, also representing a medium effect size. Proficiency scores improved significantly as well, $t(20) = -2.17, p = .04, g = -0.46, 95\% \text{ CI } [-0.89, -0.02]$, which corresponds to a small effect size. In contrast, Ethics did not show a statistically significant change, $t(20) = -1.54, p = .14, g = -0.32, 95\% \text{ CI } [-0.75, 0.10]$, with a small effect size.

Considering the nature and design of the DLPP, these findings were somewhat expected as the primary focus in workshops was on Planning, Designing and Implementing with the areas of Ethics and Proficiency not being dealt with in as much detail. Still, it is notable that increases were observed across each of the factors.

Descriptive statistics for each ICT-TPACK factor for the Year 2 cohort at pre- and post-test are presented in Table 3. These descriptive data provide contextual information for the statistically significant changes identified through inferential analysis. Fig. 2 provides a visual representation of the distribution of Year 2 PSTs' pre- and post-intervention

Table 3
Descriptive statistics for TPACK factors (Year 2).

Time	variables	n	mean	95% CI [LL; UL]	sd	min	max	se
Pre-test	Planning	30	3.58	[3.42; 3.73]	0.41	2.75	4.38	0.08
	Designing	30	2.81	[2.55; 3.06]	0.68	1.67	5	0.12
	Implementing	30	3.82	[3.68; 3.97]	0.39	3.17	5	0.07
	Ethics	30	4.04	[3.79; 4.29]	0.67	2.67	5	0.12
	Proficiency	30	3.41	[3.16; 3.65]	0.65	2	5	0.12
Post-test	Planning	25	4.02	[3.83; 4.21]	0.47	3	5	0.09
	Designing	25	3.38	[3.09; 3.67]	0.7	1.83	5	0.14
	Implementing	25	4.18	[4.01; 4.36]	0.42	3.33	5	0.08
	Ethics	25	4.37	[4.15; 4.59]	0.54	3.5	5	0.11
	Proficiency	25	3.79	[3.47; 4.10]	0.76	2.5	5	0.15

Note. Note: CI = confidence interval; LL = lower limits of 95% CI; UL = upper limits of 95% CI; sd = standard deviation; se = standard error.

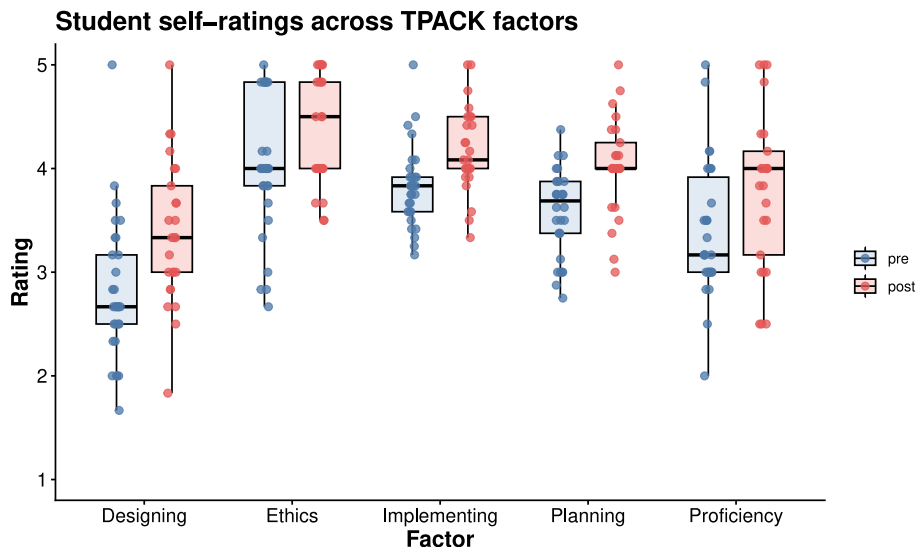


Fig. 2. Boxplot of student self-ratings across TPACK factors pre/post.

self-ratings across the ICT-TPACK factors and is included to illustrate the statistically significant changes identified through the paired-samples t-tests.

Preliminary screening indicated that skewness and kurtosis values for all variables fell within the acceptable range of -2 to $+2$, indicating no substantial departures from normality (Hair Jr et al., 2021). In order to determine if there were any statistically significant differences between the Year 2 and Year 3 cohorts' self-ratings a series of independent-samples t-tests were conducted on each of the factors, with Welch's correction applied in all cases due to unequal variances.

Significant differences were found in participants' scores for Planning, $t(43.68) = 2.90, p = .006, g = 0.84, 95\% \text{ CI } [0.24, 1.43]$, indicating a large effect size. Implementing also showed a significant difference, $t(37.69) = 2.74, p = .009, g = 0.80, 95\% \text{ CI } [0.21, 1.40]$, reflecting a large effect size. Additionally, a significant difference was found for Proficiency, $t(44.07) = 2.29, p = .03, g = 0.66, 95\% \text{ CI } [0.07, 1.25]$, representing a medium effect size. In contrast, no significant differences were found for Designing, $t(39.36) = -1.67, p = .10, g = 0.49, 95\% \text{ CI } [0.10, 1.07]$, and Ethics, $t(38.88) = -1.74, p = .09, g = 0.51, 95\% \text{ CI } [-0.07, 1.09]$, with small and medium effect sizes respectively, that were not statistically significant. Descriptive statistics for the Year 3 cohort are presented in Table 4.

Overall, the quantitative findings indicate that participation in the DLPP was associated with statistically significant improvements in PSTs' self-reported digital competence across four of the five ICT-TPACK factors, with the exception of Ethics. Differences observed between the Year 2 and Year 3 cohorts may reflect cohort-level differences and revisions made to the DLPP prior to the Year 2 cohort's participation, however, in

Table 4
Descriptive statistics for TPACK factors (Year 3).

Factor	n	Mean	95% CI [LL; UL]	sd	min	max	se
Planning	22	3.61	[3.40; 3.83]	0.49	3	5	0.1
Designing	22	2.98	[2.59; 3.38]	0.9	1.5	5	0.19
Implementing	22	3.77	[3.51; 4.03]	0.58	2.58	5	0.12
Ethics	22	4.05	[3.73; 4.36]	0.71	2.83	5	0.15
Proficiency	22	3.27	[2.93; 3.62]	0.77	1.67	5	0.16

Note. Note: CI = confidence interval; LL = lower limits of 95% CI; UL = upper limits of 95% CI; sd = standard deviation; se = standard error.

the absence of pre-intervention data for the Year 3 group, no inferences about change over time can be made.

4.2. Qualitative focus group findings

The analysis of the focus group data revealed several important insights related to the DLPP, as well as broader considerations for integrating digital literacy in schools and embedding digital competence development within initial teacher education programmes. Overall, participants recognized the inherent value of the programme and appreciated the opportunities it provided. However, differences emerged between the programme's individual components, particularly between the digital education workshops led by academic staff and the industry partner's workshops. Participants also shared a range of experiences regarding access to technology in their placement schools, noting that some had significantly more access than others. In discussing

their development of digital competence, participants reflected on their own sense of preparedness to teach digital literacy and use technology effectively with students. These reflections aligned with wider conversations about the need to integrate digital skills more fully into secondary level curricula and initial teacher education. Finally, participants demonstrated an increasing ethical awareness of the use of digital technologies in education, acknowledging the challenges and responsibilities these tools present. The qualitative findings were organized into four key themes.

1. Context, Consistency and Communication
2. Pupil vs Teacher Digital Literacy Development
3. Best Practice for Integration of Digital Skills & TPACK
4. Ethical Considerations in Technology Use

The qualitative findings will be presented using direct quotations from PSTs in the focus group interviews. Each quotation will be annotated with the participant's year group, focus group number, and PST identifier in the format: Y[X], FG[X], PST[X].

4.2.1. Theme 1: context, consistency, and communication

This theme explores the varied experiences the PSTs had with technology in their schools, underscoring the significance of the need for consistent technological infrastructure and effective communication. Several participants highlighted the inconsistent availability of technological resources, which affected their teaching experiences. One PST explained, "A big problem can be schools can have a lot of Chromebooks for all the students. But if there's not someone actively taking care of them, there's one broken there's ones missing. There's students who don't know their password. Stuff like that happens all the time" (Y3, FG1, PST3). This inconsistency often forced PSTs to adjust their plans on the spot, which compromised the quality of their lesson. The unpredictability of technology's availability and functionality in different classrooms added another layer of complexity to their lesson planning.

Moreover, the need for dedicated technical support within schools was a recurrent point of discussion. One participant emphasized, "I think in every school there should be someone who's in charge of it and that's their sole job to just keep everything running" (Y3, FG1, PST1). This highlights the importance of having specialised staff to maintain and troubleshoot technological resources, ensuring that these tools are reliable and readily available when needed, particularly when there could be varied skill levels among staff.

Communication challenges also emerged, particularly around the availability and functionality of technology. The PSTs often faced issues when technological tools did not work as expected, leading to impromptu changes in lesson plans. One participant shared, "Every room can vary so much ... you kind of change it up and go okay well we're just not going to use the PowerPoint today. And we're going to just use the board and marker" (Y2, FG2, PST2). This reflects the necessity for better communication and coordination regarding the state and availability of technological resources, as it directly affected lesson planning and execution.

4.2.2. Theme 2: pupil vs teacher digital literacy development

This theme captures the emphasis participants placed on both their own and their students' digital literacy development, highlighting the efforts required to bridge the gap between pupils' and PSTs' familiarity with digital tools.

The PSTs often found that their assumptions about pupils' digital literacy levels were higher than the reality. One participant noted, "We assume that the kids are going to be able for all of this ... and then I had to really rein back in my lessons after kind of week two and three when I realized they actually really don't know what I'm talking about" (Y2, FG1, PST3). This mismatch required PSTs to recalibrate their expectations and instructional strategies, often providing more foundational instruction on digital tools than initially anticipated. Additionally, the importance of foundational digital skills was emphasized over advanced technical

knowledge. One teacher stated, "I think it's really important to actually get the students to that level that they can function on a daily basis using just very normal software like nothing crazy like not to be this expert coder but just to be able to use your computer and function" (Y2, FG1, PST2). This highlights the necessity of ensuring pupils are proficient with basic digital tools and platforms.

The PSTs also discussed the need for a structured approach to developing digital literacy across different age groups in the context of a discussion about their subjects. One participant suggested, "There needs to be some sort of maybe like overseeing factor where there are milestones the kids need to have in terms of digital literacy going forward" (Y2, FG2, PST2). This reflects the desire for a more standardised curriculum that ensures all pupils achieve a baseline level of digital competence.

Moreover, some PSTs felt underprepared to teach digital literacy due to gaps in their own training. One participant shared, "I don't feel that I have the sufficient skills to teach using this technology to explore using these technologies" (Y3, FG1, PST2). This sentiment underscores the need for ongoing professional development and support for PSTs to ensure they can effectively integrate digital literacy into their teaching practices.

4.2.3. Theme 3: best practice for integration of digital literacy skills & TPACK

Participants recognized the value and necessity of integrating digital skills and Technological Pedagogical Content Knowledge (TPACK) into the curriculum of initial teacher education programmes.

The integration of digital literacy across various subjects, rather than treating it as a standalone topic, was raised. Participants emphasized the importance of revisiting digital pedagogy at multiple points across the programme, rather than confining it to isolated workshops. This approach would ensure that digital literacy is reinforced throughout the PSTs' educational journey, allowing them to build on their skills incrementally.

In the context of integrating digital literacy skills into secondary level curricula, the participants also highlighted various challenges. The current curriculum structure, with its heavy content load, often left little room to develop students' digital skills. One PST expressed this concern, saying, "One of the main issues with the curriculum at the moment is there's too much content to fit into the time that we have to teach that content" (Y3, FG1, PST2). While the integration of digital literacy skills in secondary level curricula is viewed as a cross-curricular element, the connections and opportunities to do so effectively are not always self-evident. The lack of specific training and resources for integrating digital literacy skills into different subjects was another challenge. One participant noted, "We need more specific training to that subject ... But I'm sure there's plenty of resources out there that are a lot more beneficial to that specific subject that we just don't know about" (Y2, FG2, PST4). This highlights the need for targeted professional development and resources sharing among educators to effectively integrate digital skills into their teaching practices. Additionally, the disparity in technological resources across different schools posed a significant barrier to the consistent integration of digital literacy. One participant shared, "Not all schools now have like iPads ... there's only one computer room in the whole school" (Y3, FG1, PST3). Inequality in access to technology can hinder efforts to standardize digital literacy skills education across the education system.

4.2.4. Theme 4: ethical considerations in technology use

Awareness of ethical considerations in technology use was evident among the participants, who discussed a range of issues including the digital divide, equality of access, plagiarism, and data privacy. These considerations are essential for responsible and effective integration of technology in education.

The digital divide was a significant concern, with participants highlighting the need for equitable access to technology. One PST noted, "You can't assume what people have available to them and what they can and can't use when they're not in school" (Y3, FG1, PST1). This reflects the challenge of ensuring all pupils have the necessary tools to participate

fully in digital learning, which is crucial for fostering an inclusive educational environment.

Plagiarism and data privacy were also major ethical concerns discussed by the participants. The rise of new technologies such as AI has made it increasingly difficult to ensure academic integrity. One participant stated, *“I think it'd be very difficult to tell if this is a student's original work or is there something written by a bot or a computer”* (Y2, FG1, PST2). This underscores the need for educators to develop strategies to detect, prevent and address plagiarism, ensuring that PSTs understood the importance of originality and academic honesty. Another PST discussed the importance of educating pupils about responsible technology use. One participant highlighted the significance of teaching students about copyright and plagiarism, saying, *“In terms of digital skills and literacy, there is a big emphasis to teach your students how to avoid copyright and plagiarism”* (Y3, FG1, PST2). This awareness is vital for helping students navigate the digital world responsibly and ethically.

The issue of data privacy was also a notable concern of the PSTs. One participant mentioned, *“The reason the phones got banned in my school was GDPR reasons students were taking photos of each other”* (Y2, FG2, PST1). This highlights the potential for misuse of technology and the importance of implementing policies and practices to protect pupils' and teachers' privacy.

In addition to these concerns, the participants emphasized the need for ongoing dialogue and education around ethical issues related to technology. One PST suggested that ethical considerations should have been an integral part of digital literacy education, ensuring that pupils were not only proficient in using technology but also understood the ethical implications of their actions.

5. Discussion

Overall, the DLPP was associated with positive changes in PSTs' self-reported digital competence, with perceived improvements evident across the range of factors identified in the ICT-TPACK STEM Scale. The programme's design, combining active, hands-on workshops with a digitally focused placement, appears to have been particularly effective and aligns with broader evidence in the literature for active, experiential approaches to developing teacher digital competence (Gabarda Méndez et al., 2023; Miguel-Revilla et al., 2020). However, while these gains are encouraging, a critical reflection on the findings reveals both the potential and the limitations of such initiatives within broader educational and technological landscapes.

The variance in digital competence observed between the Year 2 and Year 3 cohorts highlights the influence of contextual and programmatic factors, including opportunities for authentic practice and revisions to the DLPP. As this comparison is cross-sectional, it does not permit conclusions about change over time but underscores the importance of sustained and coherent approaches to developing digital competence within ITE. The revisions to the DLPP, particularly the addition of academic staff with digital education expertise and the redesign of workshop content, could have also contributed to the improved outcomes among Year 2 participants. This underscores the importance of sustained institutional support and expertise in shaping meaningful professional learning experiences a point echoed in critiques of overly technicist approaches to teacher competence (McGarr, 2019).

Importantly, the low-stakes nature of the placement assessment and the focus on structured reflective practice appear to have been crucial to the programme's success. By reducing the high-stakes performance pressures often associated with traditional placements (McGarr, 2021), the DLPP created a space for experimentation and critical engagement with digital tools. This aligns with evidence that reflection is key to developing not just technical skill but also pedagogical and ethical awareness in digital competence (Baran et al., 2019). Reflection, in this context, enabled PSTs to grapple with real-world challenges, including infrastructural deficits and the digital divide (Burns, 2023; Mohan et al., 2020), echoing calls for teacher education to engage critically with the

social and ethical dimensions of technology (Fawns, 2022; Selwyn, 2019).

However, the varied experiences across placement schools reveal significant systemic issues in the enactment of national digital strategies. Despite the assumption that partner schools would have adequate infrastructure and support, PSTs encountered gaps in technology access, functionality, and technical support, highlighting persistent implementation barriers within the Irish context (Department of Education, 2022). These findings reflect wider concerns about the uneven nature of digital integration in schools and the risk of policy optimism masking infrastructural realities (Williamson, 2021). Addressing these challenges requires stronger collaboration between ITE providers and schools, including clearer communication about school contexts, available resources, and mechanisms for accessing technology. Without such alignment, teacher digital competence risks becoming an individual responsibility, disconnected from the broader systemic conditions that shape its use.

A striking insight from the focus groups was the participants' emphasis on their pupils' digital literacy development, an area that, while outside the explicit scope of the DLPP, emerged as a central concern. PSTs quickly realized that assumptions about students as digital natives (Reid et al., 2023) were largely unfounded. This myth of the digital native led to a mismatch between expected and actual pupil competence, forcing PSTs to adapt lessons and recalibrate their understanding of digital literacy as a foundational, not assumed, skillset. The absence of clear curricular structures or milestones for pupil digital literacy further complicates this issue. While current Irish curricula reference key skills to be developed through digital means (Department of Education & Skills, 2015), these are often fragmentary and inconsistently embedded. PSTs expressed uncertainty about how to integrate digital skills within subject teaching and questioned whether digital literacy should become a discrete subject. These reflections reinforce broader critiques of techno-positivist policy framings (Wallace et al., 2023), which presume seamless integration without addressing practical and pedagogical realities.

Crucially, participants called for a more integrated, approach to developing digital competence within ITE programmes, advocating for incremental, subject-specific, and critically reflective opportunities throughout their degree. This echoes Bruner (1960) notion of a spiral curriculum and aligns with critical frameworks like the PEAT model (McDonagh et al., 2021), which emphasize the need to embed ethical, pedagogical, and attitudinal dimensions alongside technical proficiency. Such an approach would counterbalance performative framings of competence critiqued in DigCompEdu (McGarr, 2019), fostering deep and contextually grounded professional agency.

Another salient theme in participants' reflections was the ethical dimension of technology use, particularly concerning plagiarism, data privacy, and the digital divide (Cheshmehzangi et al., 2023; Burns, 2023). These concerns highlight PSTs' growing awareness of the sociocultural entanglements of education, recognizing that technology integration is not value-neutral but fraught with ethical considerations. Issues such as GDPR, AI-generated content, and student data privacy featured prominently, suggesting a need for explicit engagement with digital ethics in teacher education, a dimension often underdeveloped in policy and practice.

These challenges underscore the entangled nature of pedagogy and technology (Fawns, 2022), where decisions around digital integration are shaped by social, ethical, technical, and political factors. PSTs' reflections show that navigating these entanglements requires more than technical skill, it demands critical thinking, ethical reasoning, and professional judgment. Moreover, the presence of platformisation and commercialisation pressures (Johnston & McGarr, 2022; Perrotta & Pangrazio, 2023; Selwyn, 2019) complicates these dynamics, raising questions about teacher autonomy and the privatisation of educational spaces. The DLPP, while providing a valuable scaffold for developing digital competence, sits within a broader sociocultural landscape that

teacher education must critically engage with.

Finally, as UNESCO (2023) reminds us, technology's role in education should be to enhance, not replace, the human relational core of teaching and learning. The findings from this study suggest that developing teacher digital competence is as much about nurturing critical and reflective educators as it is about technical proficiency. As PSTs identified, the goal is not to adopt technology uncritically but to use it ethically, and in ways that serve pedagogical and human purposes.

In sum, while the DLPP made important strides in advancing PSTs' digital competence, this study highlights the necessity of embedding such initiatives within a critically reflective framework that foregrounds the complex realities of schools, the ethical challenges of technology, and the relational essence of education itself.

5.1. Limitations

While this study offers important insights into the development of PSTs' digital competence through the DLPP, several limitations must be acknowledged. First, the relatively small sample size ($N = 52$) and the self-selecting nature of focus group participation may limit the generalisability of the findings. In particular, the pre- and post-test data were drawn from a small cohort of Year 2 PSTs ($n = 30$ pre; $n = 25$ post), which constrains the extent to which changes in self-reported digital competence over time can be interpreted.

Additionally, individual-level demographic data (e.g., gender, background, or prior digital training) were not collected, which limits the ability to examine how such factors may have shaped participants' self-reported digital competence. The study was also confined to one institution and specific programme context, which may not reflect the broader diversity of ITE settings.

Finally, although the ICT-TPACK Science Scale provided a structured way to assess digital competence, it primarily captures self-reported perceptions, which may not always align with observed practices. In addition, although internal consistency estimates were acceptable, the adaptation of the ICT-TPACK Science Scale for a STEM context means that the original factor structure cannot be assumed to transfer directly, and further psychometric validation would be required before the instrument could be used more broadly. Future studies could incorporate performance-based assessments, classroom observations or digital artefact analysis to enable methodological triangulation and provide a more robust evaluation of PSTs' enacted digital competence.

6. Conclusion

This study contributes to ongoing discussions around how digital competence can be meaningfully embedded within ITE through authentic, practice-oriented experiences. The findings indicate that combining structured workshops with a low-stakes, reflective placement can support PST's development of digital competence, particularly in relation to planning, pedagogical decision-making and classroom implementation. For teacher preparation programmes, this underscores the value of moving beyond standalone technology modules towards integrated approaches that allow PSTs to experiment with digital tools in real classroom contexts without the pressure associated with high-stakes assessment.

While the DLPP was situated within a STEM and secondary level context, the broader challenges addressed, including uneven technological infrastructure, ethical considerations, and the need for coherent programme-level approaches to digital competence, are relevant across subject areas and educational phases. Nevertheless, the subject-specific design of the programme suggests that digital competence initiatives may be most effective when tailored to disciplinary and contextual needs rather than applied generically.

Future research should examine the longer-term sustainability of PSTs' digital competence development through longitudinal designs and explore how school contexts and cooperating teachers shape enactment

in practice. Studies incorporating observational or performance-based measures would further strengthen understanding of how self-reported competence translates into classroom teaching.

CRedit authorship contribution statement

Keith Young: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Zerrin Doğança Küçük:** Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization. **Thomas Delahunty:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Majella Dempsey:** Writing – review & editing, Investigation, Formal analysis, Data curation, Conceptualization. **Nika Maglaperidze:** Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare no conflicts of interest related to this study.

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Data availability

The authors do not have permission to share data.

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