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Developing Digital Literacy in Pre-Service Primary School Teachers Through a Massive Open Online Course and Project-Based Learning

Alenka Žerovnik[1]

The present paper examines the implementation of a massive open online course and project-based learning to develop the digital competences of pre-service teachers. The course design was based on the Digital Competence Framework for Citizens. The study evaluates the effectiveness of the implemented massive open online course and project-based learning in developing digital competences and assesses student satisfaction with these methods. A total of 166 students participated in the study during two academic years. The massive open online course and project assignments are compulsory components of the ICT in Education course. Students completed the massive open online course in an online classroom and demonstrated basic knowledge and understanding by achieving a passing grade. Through project-based learning, they developed digital competences at higher cognitive levels. At the end of the academic year, anonymised student feedback was collected on satisfaction with the lessons delivered, the support received from the mentors, the feedback received, and assessment through the massive open online course and project-based learning. The results indicate significant progress in digital skills, especially in digital educational content creation. The study also revealed high levels of student satisfaction with the lessons delivery, mentor support and feedback. The students rated the assessment through project-based learning positively, indicating the effectiveness of this method. Recommendations are made for improving training and promoting digital competences of students. The study contributes to understanding the importance of integrating digital literacy into educational programmes and provides guidelines for developing effective approaches to promote digital literacy, which is essential for preparing students for future professional challenges and active citizenship in a technologically advanced world.

Keywords: digital literacy development, massive open online course implementation, project-based learning, pre-service teachers, student results and satisfaction

1 Faculty of Education, University of Ljubljana, Slovenia; Alenka.Zerovnik@pef.uni-lj.si.

Razvijanje digitalne pismenosti bodočih učiteljev razrednega pouka z masovnim odprtim spletnim tečajem in s projektno zasnovanim učenjem

Alenka Žerovnik

Prispevek obravnava implementacijo masovnega odprtega spletnega tečaja in projektno zasnovanega učenja kot pristopov za razvijanje digitalnih kompetenc bodočih učiteljev. Zasnova tečaja je temeljila na Evropskem okviru digitalnih kompetenc za državljane (DigComp). Raziskava vrednoti učinkovitost izvedenega masovnega odprtega spletnega tečaja in projektno zasnovanega učenja pri razvijanju digitalnih kompetenc ter analizira zadovoljstvo študentov z obema izobraževalnima oblikama. V raziskavi je v dveh študijskih letih sodelovalo 166 študentov. Opravljen masovni odprti spletni tečaj in projektne naloge so obvezni elementi predmeta IKT v izobraževanju. Študentje so tečaj opravili v spletni učilnici ter s pridobitvijo pozitivne ocene izkazali osnovno raven znanja in razumevanja. S projektno zasnovanim učenjem so razvijali digitalne kompetence na višjih kognitivnih ravneh. Ob koncu študijskega leta so bili zbrani anonimizirani odzivi o zadovoljstvu študentov z izvedbo učnih enot, s podporo mentorjev, prejetimi povratnimi informacijami ter z ocenjevanjem v okviru masovnega odprtega spletnega tečaja in projektnega dela. Izsledki kažejo na pomemben napredek v digitalnih spretnostih, zlasti na področju ustvarjanja digitalnih izobraževalnih vsebin. Raziskava prav tako poudarja visoko zadovoljstvo študentov z izvedbo pouka, mentorsko podporo in s povratnimi informacijami. Študentje so pozitivno ocenili tudi ocenjevanje v okviru projektno zasnovanega učenja, kar potrjuje učinkovitost tega pristopa. V zaključku so podana priporočila za izboljšanje izobraževalne prakse in spodbujanje razvoja digitalnih kompetenc študentov. Raziskava prispeva k razumevanju pomena vključevanja digitalne pismenosti v izobraževalne programe in ponuja usmeritve za oblikovanje učinkovitih pristopov za krepitev digitalne pismenosti, ki je ključna za pripravo študentov na prihodnje profesionalne izzive in aktivno državljanstvo v tehnološko napredni družbi.

Ključne besede: razvoj digitalne pismenosti, implementacija masovnega odprtega spletnega tečaja, projektno zasnovano učenje, bodoči učitelji, rezultati in zadovoljstvo študentov

Introduction

Digital literacy has become an increasingly important competence for educators in the twenty-first century, transforming from an optional skill to a professional necessity (Falloon, 2020; Redecker, 2017). As primary education increasingly integrates digital technologies into pedagogical practices, teachers must develop not only technical proficiency but also the ability to leverage these tools for effective teaching and learning (Admiraal et al., 2016). This educational landscape demands that teacher preparation programmes adapt to equip future educators with comprehensive digital competences that encompass both technical skills and pedagogical application (Chilla et al., 2025; Instefjord & Munthe, 2017; Tondeur et al., 2019). By fostering these competencies, teacher preparation programmes can ensure that educators are not only proficient in using technology but also adept at integrating it meaningfully into their curricula to support all learners effectively.

Digital competence extends beyond technical skills to include critical dimensions such as information evaluation, ethical communication, creative content development and privacy awareness (Vuorikari et al., 2022). The rapid digital transformation of education, accelerated by the COVID-19 pandemic, has emphasised the importance of digital literacy among educators (Sánchez-Cruzado et al., 2021). This global shift has revealed significant disparities in teachers' preparedness to navigate digital environments and implement technology-enhanced learning, with many pre-service and in-service teachers reporting feelings of inadequacy and uncertainty (Falloon, 2020; Gudmundsdottir & Hatlevik, 2017).

Many teacher preparation programmes, however, still emphasise basic technical skills without sufficiently linking them to pedagogy. This approach often fails to prepare pre-service teachers to apply technology meaningfully in real classroom scenarios (Falloon, 2020; McGarr & McDonagh, 2020). Empirical evidence indicates that while pre-service teachers comfortably learn to use new tools, they frequently lack the pedagogical knowledge required to apply these tools effectively in classroom contexts (Røkenes & Krumsvik, 2016; Tondeur et al., 2019). As a result, new teachers may feel adept with tools yet uncertain how to leverage them for deeper learning outcomes.

The European Digital Competence Framework for Citizens (DigComp) provides a structured approach to conceptualising and developing digital literacy across five key areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari et al., 2022). This framework guides digital literacy initiatives across educational

contexts, offering a comprehensive taxonomy of skills required for effective technology integration. Aligning teacher education with such frameworks is increasingly seen as vital for developing not just technical skills but also a well-rounded digital pedagogy (Redecker, 2017; Vuorikari et al., 2022). Since its initial development, DigComp has evolved to address emerging technological and social challenges, with the latest iteration (DigComp 2.2) expanding to include competences related to artificial intelligence, emerging data technologies and misinformation (Vuorikari et al., 2022). This evolution reflects the dynamic nature of digital literacy, which continues to transform as technological landscapes shift. For teacher education, these developments necessitate adaptive approaches that can respond to emerging digital challenges while maintaining a focus on pedagogical application (McGarr & McDonagh, 2021). For pre-service teachers specifically, the complementary DigCompEdu framework addresses educators' professional needs (Redecker, 2017). Developing competence across these domains proves crucial for both personal proficiency and the ability to foster digital literacy among their future students (Foulger et al., 2017; Røkenes & Krumsvik, 2016).

In response, innovative instructional strategies are being explored to more holistically build teachers' digital competence. Two approaches have gained particular attention: massive open online courses (MOOCs) and project-based learning (PBL). MOOCs offer structured, self-paced learning at scale and have been used in teacher education to deliver foundational content aligned with competency frameworks. They excel at imparting declarative knowledge and basic concepts to large cohorts. However, conventional MOOCs largely rely on video lectures and quizzes, which limits opportunities for active learning and contextual skill application. Studies have pointed out that while MOOCs efficiently transmit knowledge, their low interactivity and one-size-fits-all design make it difficult for learners to develop higher-order thinking or situational judgment (Margaryan et al., 2015).

In contrast, PBL is a constructivist, learner-centred method that engages students in complex, authentic tasks over extended periods (Guerra et al., 2017; Maros et al., 2021; Ribeiro et al., 2023). By working on real-world projects, learners practise collaboration, creative problem-solving and critical thinking, all of which are essential for mastering higher-order digital competences. Empirical evidence shows that PBL not only reinforces content mastery but also enhances motivation and the ability to transfer knowledge to new contexts (Al-Busaidi & Al-Seyabi, 2021; Granado-Alcón et al., 2020; Guo et al., 2020). Technological tools that support collaborative project work, such as digital platforms designed for teamwork, have been shown to further increase student participation and

motivation, as well as the overall quality of the learning process (Salas-Rueda et al., 2022). In teacher education, this means pre-service teachers get hands-on experience designing and implementing tech-supported learning activities, thereby strengthening their technological-pedagogical integration skills (Kokotsaki et al., 2016; Zhang & Ma, 2023). The drawback is that PBL can be resource-intensive and difficult to scale in large programmes, often requiring extensive mentoring and iterative feedback. Thus, each approach addresses different needs: MOOCs provide breadth and scalability for foundational knowledge, whereas PBL offers depth and authenticity for applied skills.

The research gap and the research problem

Combining these complementary approaches presents a novel strategy to develop digital competence across multiple cognitive levels. A hybrid instructional design that integrates MOOC-based content delivery with PBL application could allow pre-service teachers to first acquire core knowledge and then immediately apply it in authentic settings. This promises a more complete learning experience, scaffolding from lower-order learning (understanding concepts) to higher-order performance (creating and implementing digital solutions). Despite this intuitive appeal, such hybrids remain underexplored in teacher education research. Few studies have systematically examined integrating an MOOC with PBL in a pre-service teacher programme, and empirical evidence on its effectiveness is limited (Admiraal et al., 2019; Chanpet et al., 2020; Tondeur et al., 2019). Moreover, there is a lack of insight into how teacher candidates experience these blended environments. Questions remain about how mentorship and feedback function in a scaled course, and how students perceive the value of PBL as a learning method. Addressing this gap is important, as understanding student perspectives can inform better design and support mechanisms for future implementations.

The present study investigates a hybrid xMOOC–PBL model in a compulsory ICT in Education course for pre-service primary school teachers at the University of Ljubljana. We focus primarily on how knowledge and skills acquired through the xMOOC transfer to project-based tasks and contribute to students' digital competence development. Detailed information on the participants, the course structure and the tasks is provided in the Method section.

Research questions

The aim of the study is to answer the following research questions:

RQ1: How does success in xMOOCs and performance in project-based assignments relate to the development of comprehensive digital literacy?

RQ2: To what extent are students satisfied with the lab work and seminars in the ICT in Education course, and how do they perceive the relevance and usefulness of the acquired knowledge for their future professional roles?

RQ3: How do students evaluate the quality and effectiveness of the teacher's mentoring support during PBL, and what factors influence their satisfaction with the mentoring process?

RQ4: How do students assess the feedback they received on their assignments in terms of content quality, thoroughness, clarity and alignment with assignment requirements?

RQ5: How do students perceive PBL as a method of assessment in the ICT in Education course?

These research questions aim to provide a holistic understanding of how structured digital learning and applied project work interact in fostering meaningful digital literacy. The study not only evaluates measurable outcomes but also foregrounds student experiences as essential for improving instructional design in teacher education.

Method

This study was conducted in the compulsory ICT in Education course at the Faculty of Education, University of Ljubljana. The course combines an xMOOC for foundational digital competence acquisition and project-based learning (PBL) for higher-order skills. The course design aligns with the DigComp framework. In line with Rodriguez (2013), the online course was implemented as an xMOOC – a closed, self-paced course for enrolled students – rather than an open-enrolment MOOC.

Participants

The study involved 166 students (151 female, 15 male) enrolled in the ICT in Education course at the University of Ljubljana across two academic years (2022/23: 76; 2023/24: 90). All of the participants completed the mandatory xMOOC and

project-based assignments. At the end of each semester, 75 students (33 from 2022/23 and 42 from 2023/24) voluntarily completed an anonymous online survey.

Instruments

The survey combined Likert-scale and open-ended items. Satisfaction with lab work, seminars and mentor support was rated on a 5-point scale. Perceived knowledge usefulness used a 6-point scale. Mentor feedback was assessed on a 3-point scale across four aspects: content quality, clarity, thoroughness, and alignment with assignment goals. The students rated the PBL method on a 4-point scale. The choice of different scales was deliberate: 5-point scales for seminar/lab satisfaction allow a neutral midpoint; a 6-point scale for perceived usefulness removes neutrality to elicit a clearer stance; a concise 3-point scale for mentor feedback emphasises clear distinctions (insufficient–adequate–excellent); and a 4-point scale for evaluating PBL similarly avoids neutrality and promotes decision-making.

The internal reliability of the survey subscales was assessed using Cronbach's alpha. The four mentor feedback items demonstrated acceptable internal consistency ($\alpha = .745$). In contrast, the subscale comprising lab work satisfaction, seminar satisfaction, knowledge gained and usefulness of knowledge showed lower internal consistency ($\alpha = .589$), likely due to conceptual variation across cognitive and affective items. All of the items were nonetheless retained due to their theoretical and contextual relevance.

In addition to the survey, two performance-based measures were collected: scores from the xMOOC and project assignments. The xMOOC was structured around four DigComp competence areas. Each area included self-paced tasks with embedded automatic feedback, similar to other higher education online courses that integrate interactive elements such as quizzes and collaborative assignments to promote engagement and skill development (Dagarin Fojkar & Berčnik, 2023). Students earned a badge for each area and a final badge upon full completion. xMOOC performance was expressed as a percentage based on total points earned. The project component consisted of four individual assignments, each evaluated using a rubric covering pedagogical and technical criteria. The total project score was also recorded as a percentage. These two performance indicators provided objective measures of the students' digital competence at both foundational and higher-order levels. The xMOOC was delivered via the Arnes Moodle LMS. Open Badges were issued upon successful completion of each module and a final badge for course completion; the badges reflected pass/fail based on meeting a 50% points threshold (no graded badge levels).

Research design

The study used a mixed-methods approach, combining quantitative and qualitative data. Quantitative sources included xMOOC scores, PBL scores and student survey responses. Descriptive statistics (means, medians, modes, standard deviations) were computed for all variables. Due to non-normal data distribution (Shapiro-Wilk $p < .001$), non-parametric tests were applied.

In order to analyse the relationship between foundational and higher-order digital competences, a simple linear regression was conducted using xMOOC scores to predict project performance. Due to the anonymous nature of the survey, regression analyses were limited to non-survey variables. In addition, a Wilcoxon signed-rank test and Spearman's correlation were used to assess score differences and associations between the two assessment formats. Survey-based variables were analysed independently using descriptive and thematic methods.

Course performance was assessed using xMOOC completion scores and individual project assignments. The xMOOC consisted of auto-graded tasks covering four DigComp areas. Student performance was expressed as a percentage score based on the total number of points achieved. A minimum threshold of 50% was required to pass. The same criterion applied to the project-based learning, which was completed individually and consisted of four assignments.

xMOOC scores were automatically generated based on task completion and accuracy. Project scores were assigned by instructors using a rubric that evaluated both pedagogical and technical criteria. The xMOOC was designed to support knowledge acquisition at the first three cognitive levels of Bloom's taxonomy (remember, understand, apply), while project assignments required students to demonstrate the same digital competencies at higher levels (analyse, evaluate, create). Survey responses captured the students' satisfaction with course components, perceived knowledge gained and its usefulness, support received from the mentor, and quality of feedback. The questionnaire included four 6-point Likert-scale items measuring satisfaction and perceived usefulness, four 3-point items assessing mentor feedback quality, and one 4-point item evaluating the perceived value of project-based learning as a learning method.

The first project assignment involved creating a post in a collaborative e-portfolio environment, targeting competencies in information literacy, digital communication and collaboration, copyright and data protection. The second assignment focused on creating digital images for educational purposes. In the third task, the students designed an infographic on an educational topic. The final assignment required the creation of an educational video, with attention to principles of video pedagogy. Each project was evaluated by the instructors

according to predefined rubric criteria, and the total project score was expressed as a percentage.

Qualitative data from the open-ended survey responses were analysed using reflexive thematic analysis (Braun & Clarke, 2020). Coding was performed separately for lab work, seminar sessions, mentoring support and PBL. Frequency counts were used to support theme prominence and identify dominant patterns.

The study adhered to ethical guidelines for research involving human participants. Informed consent was obtained from all of the participants to ensure that they were aware of the study's purpose and their right to withdraw at any time. Data were collected in an anonymised form to protect the participants' privacy.

Results

Analysis and comparison of xMOOC and project assignment scores in the ICT in Education course

Figure 1 presents individual student scores on xMOOC assessments and project assignments. The students are sorted by increasing project scores. The purple line represents xMOOC scores, the green line represents project scores, and the black dotted line shows the logarithmic trend of xMOOC scores.

Figure 1
xMOOC and project assignment scores with a black-dotted line indicating the xMOOC score trend

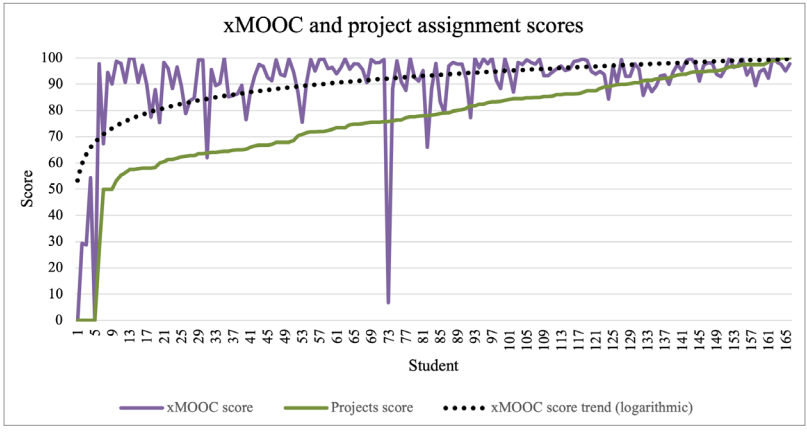

Figure 1 shows a positive association between xMOOC and project scores. Students with lower xMOOC scores tend to also have lower project scores. This is particularly visible at the lower end of the distribution. The logarithmic trend line of xMOOC scores confirms this relationship, indicating that lower-performing students in the xMOOC also performed worse in the projects.

In order to better explore this relationship, a Wilcoxon signed-rank test was conducted due to non-normal data distribution (Shapiro-Wilk $p < .001$ for both variables). The results revealed a statistically significant difference between the two sets of scores ($Z = -9.796$, $p < .001$), with project scores being lower than xMOOC scores in most cases (138 out of 164). This aligns with the nature of the assessments: the xMOOC focused on foundational knowledge and understanding, while the project assignments required higher-order skills such as application, analysis and creation, reflecting the upper levels of Bloom's revised taxonomy. It was therefore expected that the students would find the projects more cognitively demanding.

The positive association seen in Figure 1 suggests that students with weaker performance in foundational tasks also struggled with more complex assignments. Although this may appear intuitive, establishing this empirically is essential for instructional design, as it highlights the importance of scaffolding between lower- and higher-order digital competencies.

Spearman's rank-order correlation was used to quantify the strength of this association, revealing a weak but statistically significant positive correlation between xMOOC and project scores ($\rho = .231$, $p = .003$, $N = 164$). While students who scored higher in the xMOOC generally achieved higher project scores, the modest correlation indicates that the two assessment formats measured distinct dimensions of digital competence. The xMOOC primarily evaluated lower-order skills (remember, understand, apply), whereas the projects required the synthesis and creative application of knowledge in realistic educational contexts.

In order to further assess the predictive value of foundational knowledge, a simple linear regression was conducted with xMOOC score as the predictor and project score as the outcome variable. The regression model was statistically significant, $F(1, 162) = 51.993$, $p < .001$, explaining 24.3% of the variance in project performance ($R^2 = .243$). xMOOC performance significantly predicted project outcomes ($B = .692$, $\beta = .493$, $p < .001$), indicating that for every one-point increase in xMOOC score, the project score increased by approximately 0.69 points on average. These findings confirm that foundational digital competence acquired through structured online learning contributes

meaningfully to performance in more complex, open-ended project tasks.

Analysis of student satisfaction with course implementation and perceived usefulness of the knowledge gained in the ICT in Education course

Table 1 presents the descriptive statistics for student responses regarding satisfaction with lab work, satisfaction with seminars, knowledge gained, and perceived usefulness of the knowledge.

Table 1

Descriptive statistics of student responses regarding satisfaction with course implementation and perceived usefulness of the knowledge gained (N = 75)

	Satisfaction with lab work	Satisfaction with seminars	Knowledge gained	Usefulness of the knowledge
M	4.57	4.48	5.27	5.36
Me	5.00	5.00	5.00	5.00
Mo	5	5	5	5
SD	.597	.665	.644	.671
Min	3	3	4	3
Max	5	5	6	6

Note. *M* = mean; *Me* = median; *Mo* = mode; *SD* = standard deviation; *Min* = minimum; *Max* = maximum.

The students reported a high level of satisfaction and perceived value across course components, with mean scores ranging from 4.48 to 5.36 on a 6-point scale. The highest mean score (*M* = 5.36) reflected the perceived usefulness of the knowledge gained, indicating that the students found the content highly relevant to both their studies and their future roles as teachers. Median and mode values were consistently 5, and low standard deviations indicated limited variability in responses (Table 1).

Lab work received a mean rating of 4.57 (*SD* = .597), with 62% of the students "Very satisfied" and 32% "Satisfied". Seminar sessions followed closely (*M* = 4.48, *SD* = .665), with 57% "Very satisfied" and 33% "Satisfied". For perceived knowledge gain, 89.3% of the students gave a score of 5 or 6 (*M* = 5.27), while 91.4% rated the usefulness of the knowledge as 5 or 6 (*M* = 5.36), confirming a strong alignment between course content and professional relevance.

In order to better understand these ratings, thematic analysis was conducted on 129 open-ended responses. A total of 68 responses related to lab work

and 61 to seminars. For lab work, five dominant themes emerged: *Overall satisfaction* (n = 22), *Teaching quality* (n = 19), *Assignments and tasks* (n = 16), *Instructor support* (n = 7) and *Course materials and feedback* (n = 4). The students appreciated the structured design, clarity of instruction, logical task progression and responsive support. A few students raised concerns about workload volume and suggested improvements such as better pacing and resolving technical issues.

In the seminars, six main themes appeared: *Instructor quality* (n = 22), *Overall satisfaction* (n = 22), *Content relevance* (n = 21), *Engagement* (n = 16), *Connection to practice* (n = 16) and *Course materials* (n = 15). The students consistently praised the clarity, enthusiasm and practical orientation of the instruction. Interactive elements and real-world applicability were frequently mentioned as strengths. Moderate satisfaction ratings were typically linked to content redundancy, session length or irregular attendance.

These findings suggest that the combination of seminars and lab work created a coherent and supportive learning environment. The students valued the progression from theory to practice, clear explanations, individualised support, and strong alignment with professional contexts, all of which contributed to meaningful learning experiences.

Analysis of student satisfaction with the support received from the mentor

Table 2 presents the descriptive statistics for student responses regarding satisfaction with the support from the mentor. Six students indicated that they did not seek mentoring support.

Table 2

Descriptive statistics of student responses regarding satisfaction with mentoring support (N = 69)

	Satisfaction with the support from the mentor
M	4.84
Me	5.00
Mo	5
SD	.369
Min	4
Max	5

Note. M = mean; *Me* = median; *Mo* = mode; *SD* = standard deviation; *Min* = minimum; *Max* = maximum.

The students expressed high satisfaction with mentor support during PBL, with a mean score of 4.84 on a 5-point scale. Both median and mode were 5, and ratings ranged only from 4 to 5 (*SD* = .369), indicating consistent and overwhelmingly positive evaluations (Table 2). Most of the respondents rated the mentoring as "Excellent" (76%) or "Very good" (14%), while 8% reported not seeking support.

Thematic analysis of 62 open-ended responses identified eight key themes. *Usefulness* (*n* = 18) and *Support level* (*n* = 14) highlighted the mentor's practical impact on task execution and project quality. The students described the support as comprehensive, responsive and tailored to individual needs. *Clarity of communication* (*n* = 11) and *Availability* (*n* = 8) were praised, with students noting the mentor's detailed explanations, precise guidance and timely responses via multiple channels.

Additional themes included *Timely feedback* and *Improvement suggestions*, with students valuing constructive advice that helped refine their work. *Mentor attitude* was also noted, with students describing the mentor as patient, encouraging and supportive throughout the project process. Among those who did not seek help, one student acknowledged preferring independence but still recognised the potential benefit of mentoring.

The students viewed mentoring as a critical element of the PBL experience. The mentor's clarity, accessibility and personalised guidance played a key role in supporting the students through complex tasks and contributed significantly to their learning outcomes.

Analysis of student satisfaction with the feedback received from the mentor

Table 3 presents the descriptive statistics for student responses regarding satisfaction with the feedback received from the mentor.

Table 3

Descriptive statistics of student responses regarding satisfaction with the feedback received from the mentor (N = 75)

	Satisfaction with feedback in terms of content quality	Satisfaction with the thoroughness of the feedback in relation to the assignment	Satisfaction with the consistency of the feedback with assignment requirements	Satisfaction with the clarity of the feedback
M	2.88	2.88	2.88	2.84
Me	3.00	3.00	3.00	3.00
Mo	3	3	3	3
SD	.327	.327	.327	.369
Min	2	2	2	2
Max	3	3	3	3

Note. *M* = mean; *Me* = median; *Mo* = mode; *SD* = standard deviation; *Min* = minimum; *Max* = maximum.

The students rated four aspects of feedback: content quality, thoroughness, consistency with assignment requirements, and clarity. Mean scores were nearly identical across all aspects, ranging from 2.84 to 2.88 on a 3-point scale, indicating a moderate level of satisfaction. Median and mode values were consistently 3, suggesting that most of the students selected the highest possible score. The standard deviation was low across all items (*SD* = .327 to .369), indicating little variability in responses. Minimum and maximum values remained constant (2 and 3), showing a narrow distribution (Table 3). These results suggest a generally positive, though not maximal, perception of feedback quality and clarity.

Analysis of student responses regarding assessment through PBL

Table 4 presents the descriptive statistics for student ratings of PBL as a method of teaching.

Table 4
Descriptive statistics for student ratings of PBL as a method used (N = 75)

	Student ratings of project-based learning as a method used in the ICT in Education course
M	3.61
Me	4.00
Mo	4
SD	.543
Min	2
Max	4

Note. *M* = mean; *Me* = median; *Mo* = mode; *SD* = standard deviation; *Min* = minimum; *Max* = maximum.

The students rated PBL on a 4-point scale (1 = meaningless, 4 = the only meaningful approach), with a mean of 3.61 and both the median and mode at 4 (Table 4). Most of the students considered PBL highly meaningful: 63% selected the highest rating, 33% rated it as good, and only 3% viewed it as less meaningful. None of the students rated it as meaningless, indicating strong support for PBL as an effective and relevant teaching method.

Thematic analysis of 62 open-ended responses identified eight themes. *Overall value* ($n = 25$) reflected strong appreciation of PBL's relevance and depth. The students emphasised its alignment with course goals and its role in promoting deep, meaningful learning. *Practical application* ($n = 13$) and *Knowledge retention* ($n = 11$) highlighted how applying theory in real-world tasks helped solidify understanding and improve memory. *Creativity and innovation* ($n = 7$) revealed that the students valued the opportunity to design original solutions and take ownership of their learning process.

Workload ($n = 14$) emerged as both a motivator and a challenge. While many of the students appreciated the engagement that came with complex tasks, some expressed concerns about time demands and performance pressure. Other themes included *Engagement and motivation*, *Collaboration* and *Assessment approach*, which were mentioned less frequently but reinforced the overall positive perception of PBL.

A co-occurrence analysis showed that the students who rated PBL most highly (4/4) were more likely to mention *Practical application* (27.5%) and *Knowledge retention* (22.5%), while those who rated it lower (≤3) more often cited *Engagement* issues and *Workload* burdens (both 28.6%).

The findings from this section suggest that the students perceived PBL as a highly effective and meaningful learning strategy that fosters applied skills,

creativity and long-term learning. In order to maximise its benefits, however, educators should provide clear scaffolding and manage cognitive load through thoughtful task design.

Discussion

The findings of this study demonstrate the effectiveness of a hybrid instructional model that combines an xMOOC and project-based learning (PBL) to develop digital competence in pre-service primary school teachers. By integrating structured foundational learning with authentic, higher-order application, the course addressed both cognitive and pedagogical dimensions of digital literacy, aligning with the DigComp framework (Redecker, 2017; Vuorikari et al., 2022).

The positive, though modest, correlation between xMOOC and PBL scores (ρ = .231, p = .003) suggests that foundational digital knowledge contributes to (but does not fully determine) students' ability to perform complex, authentic tasks. The regression model further supports this by showing that xMOOC performance accounted for 24.3% of the variance in project outcomes. These findings support Sánchez-Cruzado et al. (2021), who argue that digital competence requires a combination of declarative knowledge and authentic practice. They also reinforce Tondeur et al.'s (2019) call for scaffolded learning approaches that bridge theoretical understanding with practical application. The gap between xMOOC and PBL scores aligns with Bloom's taxonomy, as PBL tasks required more cognitively demanding skills such as creation, evaluation and synthesis, skills that are not fully developed through passive content delivery.

The student feedback highlighted high levels of satisfaction with both the xMOOC and PBL components, particularly with the perceived usefulness of knowledge for future teaching roles. These results are in line with the findings of Svoboda and Mynaříková (2021) and Instefjord and Munthe (2017), who highlight the importance of aligning digital training with professional practice. The students appreciated the course structure, instructional clarity and real-world relevance of the assignments, which are key attributes identified by Røkenes and Krumsvik (2016) as essential for impactful digital competence development. At the same time, concerns about workload emerged, particularly in relation to the demands of PBL work. These concerns align with the findings of Janssen et al. (2019), who note that applied digital tasks often increase cognitive load and require careful instructional support to remain sustainable and effective.

Mentor support was a crucial factor in the course's success. The students consistently valued the mentor's availability, clear communication and targeted support, qualities also identified by Eller et al. (2014). These results also support Admiraal et al. (2019), who argue that mentoring in technology integration should combine pedagogical guidance with technical expertise. In the present study, the students appreciated multi-channel communication and described the feedback they received as clear, constructive and well aligned with assignment goals. Such alignment reflects the principles of constructive alignment in assessment design (Biggs, 2014) and supports Deng et al.'s (2019) view that timely, relevant feedback is essential in digital learning contexts, where students often feel uncertain about their progress.

The positive student response to PBL as a learning and assessment method strengthens the argument for its inclusion in digital literacy education. Most of the students surveyed viewed PBL as the most meaningful approach for demonstrating competence, citing its practical application, support for knowledge retention and opportunities for creativity. These outcomes reflect the established benefits of PBL in teacher education (Guo et al., 2020; Jopp, 2019; Sokhanvar et al., 2021) and validate the model's authenticity and transferability to real-world teaching contexts. While some of the students noted the workload as a challenge, this aligns with Foulger et al. (2017), who found that deep learning through authentic projects requires substantial time and cognitive effort from both learners and instructors. Nonetheless, the students generally perceived this effort as a worthwhile investment in their professional development.

The integration of MOOCs and PBL within a DigComp-aligned teacher education course offers a viable strategy for developing comprehensive digital competence. This hybrid model balances scalability with personalisation, combining the reach of online learning with the depth of authentic assessment. The findings highlight the importance of structured progression from foundational to applied learning, the value of responsive mentoring, and the potential of PBL to cultivate meaningful digital skills. As digital competence continues to evolve, such integrated approaches will be essential for preparing future educators to navigate and lead technology-rich learning environments.

The relationship between xMOOC performance and PBL outcomes

Our first research question (RQ1) examined how success in xMOOCs and performance in PBL assignments relate to digital literacy development. The results revealed a positive association between xMOOC and PBL scores,

with a significant correlation and regression analysis indicating that xMOOC performance predicted 24.3% of the variance in project outcomes. Foundational knowledge acquisition through structured online learning contributes to performance in more complex tasks. However, the modest correlation also suggests that these assessment formats measure distinct dimensions of digital competence, supporting Sánchez-Cruzado et al.'s (2021) assertion that digital competence development requires multiple complementary approaches.

The significantly lower PBL scores compared to xMOOC scores reflects the increased cognitive demands of the PBL tasks, which required the students to operate at higher levels of Bloom's taxonomy. This pattern supports Redecker's (2017) DigComp framework conceptualisation, which posits digital competence as a multi-dimensional construct requiring both knowledge acquisition and applied practice. Moreover, it confirms Falloon's (2020) findings that while MOOCs effectively develop foundational digital skills, more complex competences require opportunities for authentic application and creation.

The regression model highlights the fact that foundational knowledge, although necessary, is insufficient on its own. These findings reinforce Tondeur et al.'s (2019) call for integrated teacher education approaches that blend theory and practice. Our results empirically support the need to scaffold digital literacy instruction from lower- to higher-order competencies.

Conclusions

The present study provides empirical support for an integrated approach to digital literacy development in pre-service primary teachers, combining an xMOOC based on the DigComp framework with project-based learning. The findings show a significant, although modest, link between foundational knowledge and higher-order application, confirming that structured online learning and PBL effectively scaffold digital competence in line with Bloom's taxonomy and Redecker's (2017) multi-dimensional model.

High student satisfaction and perceived relevance indicate strong alignment between course design and professional preparation. The value placed on PBL reinforces the importance of authentic, creative tasks in developing transferable skills. Key success factors included clear instructional design, progression between components, responsive mentoring and constructive feedback. This hybrid model offers a scalable yet personalised strategy adaptable across teacher education contexts, addressing the need for comprehensive, integrated digital competence development (Tondeur et al., 2019).

Theoretical and practical implications

Our findings support the view of digital competence as a multi-dimensional construct requiring both foundational knowledge and applied practice (Redecker, 2017). The correlation between xMOOC and PBL scores indicates that these dimensions are related but distinct, highlighting the need for complementary pedagogical strategies. A hybrid model that combines structured xMOOCs with PBL addresses Falloon's (2020) concern that digital literacy initiatives often overemphasise either theory or technical skills at the expense of authentic application. Sequencing foundational content before applied tasks creates effective scaffolding from lower- to higher-order competencies. These results align with Tondeur et al. (2019), who emphasise the importance of integrating technical and pedagogical skills in authentic educational settings.

From a practical standpoint, the study supports a scalable and personalised approach to teacher education: self-paced xMOOCs for foundational learning followed by mentored PBL for skill application. The students' high satisfaction with mentoring highlights the importance of human guidance in navigating complex digital tasks, supporting Admiraal et al. (2019). The strong preference for PBL over traditional assessments suggests the value of authentic, creative assignments for evaluating digital competence. While our course-level intervention proved effective, comprehensive digital literacy development depends on broader programme integration (Røkenes & Krumsvik, 2016) and continued support into early career stages (Gudmundsdottir & Hatlevik, 2017). Future research should explore how targeted interventions like this contribute to sustained competence development within teacher education programmes.

Limitations of the study

Although the present study was comprehensive, several limitations must be acknowledged. The study was limited to a single institution with a predominantly female sample (91%), which may affect generalisability. Although this reflects typical enrolment in primary teacher education, future research should include more balanced samples to explore gender differences in digital competence development. The study also relied partly on self-reported satisfaction and usefulness, which may introduce social desirability bias. While anonymity likely reduced this risk, future work should include objective measures, such as standardised assessments or external application tasks.

The modest correlation between xMOOC and project scores suggests that factors beyond foundational knowledge influence project outcomes. The

study did not control for prior digital experience, academic ability or time investment. Future research using multivariate analyses could better isolate the impact of each learning component. Despite these limitations, the study offers strong empirical support for integrating xMOOCs and PBL to build comprehensive digital literacy in teacher education.

Practical recommendations and future research

Based on the findings of this study, several recommendations can be made to improve digital competence development in pre-service teacher education. Teacher education programmes should adopt a sequential structure that scaffolds foundational knowledge through xMOOCs into higher-order application via project-based learning. This model offers a scalable yet personalised approach adaptable across contexts. Mentoring should prioritise accessibility, clarity and comprehensive support, as students highly value human guidance alongside digital content (Admiraal et al., 2019). Instructors should maintain multiple communication channels and provide both technical and pedagogical feedback. Teaching practices should focus on authentic, creative tasks that reflect real-world classroom challenges. Given students' preference for PBL, traditional assessment methods may fall short in fostering and evaluating digital competence. At the same time, educators must carefully manage workload and cognitive demands through appropriate scaffolding.

Future research should examine how pre-service teachers transfer digital competences to professional practice through longitudinal studies. Comparative research on hybrid models would help optimise the structure between xMOOCs and PBL. Studies exploring peer collaboration could uncover new strategies for enhancing digital literacy through social learning. Additionally, investigating the use of adaptive learning technologies may reveal how to better personalise foundational training, especially given the varying digital skill levels among pre-service teachers (Tondeur et al., 2020).

Ethical statement

Ethical approval for the study was given by the Ethics Commission of the Faculty of Education of the University of Ljubljana, Slovenia.

Disclosure statement

The author has no conflict of interest to declare.

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Biographical note

Alenka Žerovnik, PhD, is a teaching assistant in computer science in education and computer science didactics at the Faculty of Education at the University of Ljubljana, with extensive teaching and research experience. She integrates innovative technologies, such as generative AI, into learning processes, emphasising project-based learning, computational thinking, and open educational resources. She utilises formative assessment and multimodal feedback to support teachers and students, and explores the ethical and pedagogical implications of AI. By contributing to digital transformation strategies and promoting digital literacy, she strives to help shape a fairer, more flexible, and more effective education system for the future.