

Special Issue Reprint

Technologies and Teacher Education

Preparing Teachers for the Digital Age

Edited by
Yu-Chun Kuo

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Technologies and Teacher Education: Preparing Teachers for the Digital Age

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Guest Editor

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Article

A Qualitative Descriptive Study of Teachers' Beliefs and Their Design Thinking Practices in Integrating an AI-Based Automated Feedback Tool

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Abstract

In this post-digital age, writing assessment has been markedly influenced by advancements in artificial intelligence (AI), emphasizing the role of automated formative feedback in supporting second language (L2) writing. This study investigates how Norwegian teachers use an AI-driven automated feedback tool, the Essay Assessment Technology (EAT), in process writing for the first time. Framed by the second and third-order barriers framework, we looked at teachers' beliefs and the design level changes that they made in their teaching. Data were collected in Autumn 2022, during the testing of EAT's first prototype. Teachers were first introduced to EAT in a workshop. A total of 3 English as a second language teachers from different schools were informants in this study. Teachers then used EAT in the classroom with their 9th-grade students (13 years old). Through individual teacher interviews, this descriptive qualitative study explores teachers' perceptions, user experiences, and pedagogical decisions when incorporating EAT into their practices. The findings indicate that teachers' beliefs about technology and its role in student learning, as well as their views on students' responsibilities in task completion, significantly influence their instructional choices. Additionally, teachers not only adopt AI-driven tools but are also able to reflect and solve complex teaching and learning activities in the classroom, which demonstrates that these teachers have applied design thinking processes in integrating technology in their teaching. Based on the results in this study, we suggest the need for targeted professional development to support effective technology integration.

Keywords: automated feedback; barriers; challenges; design thinking; lower secondary teachers; teachers' belief

1. Introduction

Teaching is a highly complex profession that demands that educators constantly make pedagogical decisions. In the context of emerging Artificial Intelligence (AI) technologies, AI presents promising opportunities; however, its integration into education relies heavily on teachers (Abel et al., 2022). In the pre-digital age, when new technology was being introduced to the educational system, the primary objective focused on enhancing teachers' digital competencies for the practical application of these technologies (McDonagh et al., 2021). The complexity of the early technological systems necessitated a focus on developing practical skills to navigate and utilize the technologies effectively. Today,

however, contemporary digital technologies, such as computers, tablets, and smartphones, feature significantly more user-friendly interfaces. Consequently, the emphasis within the education system has shifted from merely having the knowledge, understanding, and skill on how to operate and integrate these technologies within pedagogical and didactic frameworks but on how these technological tools are used effectively to improve teaching and learning (Lund et al., 2014; McDonagh et al., 2021; Mishra & Koehler, 2006). From learning management to augmented reality, teachers are continuously in need to upgrade their knowledge in adopting the changes that will enhance classroom instruction. While these technological resources promise exciting opportunities, there has been an ongoing discourse on not only being a digital literate teacher but also a digitally competent teacher (Brevik et al., 2019; Gudmundsdottir & Björnsson, 2021; Nagel et al., 2023). In being a digitally competent teacher, recent studies suggest that some teachers are the ones leading the process of technology integration and are eager to exploit the potential of technology, while some others do not share this affinity (Roblin et al., 2018; Tondeur et al., 2013).

Despite the potential of AI in education, a recent global education monitoring report advocates that educational tools should serve to enhance, but never replace, the human connections that are fundamental to teaching and learning. The report mentioned that the primary focus should be on learning outcomes rather than the mere integration of digital tools (UNESCO, 2023). As Reinders (2009) notes, knowing how to use a software program does not necessarily equate to the ability to effectively incorporate it into pedagogical practices. Previous studies on teachers' perceptions of technology integration reveal that these decisions are primarily driven by practical concerns, such as the availability of technology in schools (Ertmer, 1999). It quickly became clear that simply introducing or providing access to technology does not guarantee its integration into teaching practices, as it may still be used in ways that reflect traditional pedagogies (Vandeyar & Adegoke, 2024). The true integration of technology requires overcoming teachers' beliefs (Abedi, 2023; Ifinedo et al., 2020; Prestridge, 2012), and the pedagogical decisions that the teachers made in problem-solving, described as 'design thinking', are seen as necessary for technology integration (Johnson & Tawfik, 2022; Łuczak et al., 2023; Tsai & Chai, 2012).

A growing challenge is how teachers adapt their decision-making practices to effectively integrate AI-based tools. In this study, we argue that teachers' beliefs and their engagement in design thinking processes are essential for making thoughtful and effective decisions, especially when integrating AI-based automated feedback. Design thinking encompasses the cognitive strategies and problem-solving approaches that designers use when addressing complex challenges (Meinel & Krohn, 2022; Razzouk & Shute, 2012). The concept has gained prominence in various fields, including education. While interest in linking design thinking to education continues to grow, its practical application in classrooms remains underexplored. In the context of this study, design thinking is viewed as a useful framework for engaging teachers with real-world problems of practice. Positioning teachers as designers, particularly within innovative, feedback-oriented, and technology-supported learning environments, can foster agency and support their capacity to respond creatively and effectively to ongoing challenges in education (Scott & Lock, 2021). The challenges teachers face in practice are often complex and multifaceted, ranging from designing meaningful feedback processes, deep empathy for students' needs, to navigating communication with diverse stakeholders (Baran & AlZoubi, 2024). These so-called 'problems of practice' are open-ended and rarely have a single, clear-cut solution (research evidence). Adopting a design thinking mindset can support teachers in approaching these challenges creatively. Just as designers explore how people interact with products or systems, teachers can reflect on how students experience automated feedback, how they interpret it, respond to it, and act upon it. This perspective enables teachers to gain

deeper insights into students' learning journeys and to iteratively adapt feedback tools and strategies in more thoughtful, responsive ways. Understanding how teachers perceive and utilize AI tools in their practice can provide valuable insights into how these technologies can support and enhance their decision-making processes. Although the promise of AI in education, especially in formative assessment practices, has been widely acknowledged, there remains a gap in understanding how teachers redesign their instructional practices at a pedagogical level to accommodate these tools.

Prior research has explored the adoption of AI-driven tools in education, focusing primarily on teachers and students accessibility to technology (Ertmer, 1999), enthusiasm or resistance in incorporating technology (Elstad, 2016), initial usage and individual or organizational factors (Burner et al., 2025; Elstad & Eriksen, 2024). To our knowledge, there is a lack of studies into how teachers actively redesign their pedagogical practices and redefine their facilitation roles when using an automated feedback tool. Specifically, little is known about the design-level changes teachers make and their beliefs about integrating an AI-based automated feedback tool effectively, and how these changes influence their teaching practices. This study sought to understand and describe teachers' experiences in using an automated feedback tool for the first time, including their beliefs and how teachers iteratively redesign their pedagogical practices and make design-level changes to integrate automated formative feedback.

2. Automated Formative Feedback as an Instructional Tool

The development of an AI-based automated formative feedback system stemmed from the need to address the expensive and time-intensive process associated with employing human evaluators for large-scale standardized language assessments where a significant number of learners are evaluated (Zhao et al., 2023). Consequently, the initial development of Automated Writing Evaluation (AWE) was predominantly towards producing numerical scores for summative evaluations, while largely overlooking the provision of qualitative written feedback (Stevenson & Phakiti, 2019). The introduction of the AWE system traces back to the late 1960s with the development of Project Essay Grade (PEG) by Ellis Page and his research team (Page, 1966). Since this pioneering work, a variety of commercial and non-commercial automated scoring systems have emerged. Starting in the 1990s, alongside the advancement in AWE technologies, there has been a heightened focus on employing AWE systems for delivering written feedback, primarily for educational purposes. As such, the focus was to supplement teachers with feedback tools by not only providing an evaluative numerical score but also written feedback that will help learners in their writing.

AI has the potential to support formative assessment practices by enhancing the feedback in terms of both quantity and quality of feedback (Burner et al., 2025). In formative assessment, feedback plays a critical role in guiding student progress, identifying learning gaps, and offering support to improve learning outcomes (Hattie & Timperley, 2007; Sandal et al., 2022). The primary objectives of formative assessment include delivering constructive feedback that is tailored to individual student responses and aiding teachers in their instructional methods (Hopfenbeck et al., 2023). The use of AI in this context facilitates the broad application of formative assessment across various time frames, both cross-sectional and longitudinal. This approach enhances sustainability and efficiency, enabling educators to effectively track the progression of student learning (Zhu et al., 2020). It also assists in pinpointing the specific areas where students may lack knowledge or skills over time.

The AI based automated systems has several distinctive features such as evaluating student writing specifically offering insights on the grammatical structure (Barrot, 2020; Koltovskaia, 2020) and mechanics of language writing such as spelling, capitalization and

punctuation (Liu et al., 2017) Among other features of an automated feedback system include identifying issues related to the content, development of ideas, vocabulary and organization (Wang & Han, 2022; Wilson & Czik, 2016). Despite criticism about its length of feedback over brevity, the concern about the accuracy (Hoang, 2022; Qian et al., 2019), the evidence indicates that an automated formative feedback system has the potential to support various instructional approaches and enhance educational objectives (Shadiev & Feng, 2023). A synthesis of existing automated feedback research (Link et al., 2020; Wilson et al., 2021) shows that like any other technological tool, the teacher plays a central role in how automated formative feedback is incorporated into classroom writing instruction (Wilson et al., 2021).

2.1. Barriers to Integrating Technology

The challenges in integrating AI into education are often defined as conditions that hinder the effective implementation of technology into classrooms (Vatanartiran & Karadeniz, 2015) Research identifies differing classifications, but most frameworks distinguish between external barriers such as institutional and resource limitations (Fredrickson et al., 2014; Mustafa et al., 2024) and internal barriers, which stem from teachers' attitudes and perceptions (Makki et al., 2018). Ertmer (1999) discusses these in terms of first-order (incremental and institutional) and second-order barriers (fundamental and personal) to technology integration in education. First-order barriers encompass external factors that can impede integration, such as insufficient access to equipment, time, training, and institutional support. These factors are external to teachers. Second-order barriers are relatively seen as an internal factor, where, according to Ertmer (1999), are more intrinsic to teachers and include their pedagogical beliefs, technological beliefs, and willingness to change. These personal beliefs can obstruct the implementation of technology in classrooms. Building on this framework, Tsai and Chai (2012) argued that a third type of barrier is the lack of problem-solving capacity or what they described as 'design thinking'. They argue that this capacity is essential for teachers to creatively and effectively integrate technology into their teaching practices. Thus, while first- and second-order barriers address practical and attitudinal challenges, the third-order barrier highlights the need for teachers to develop a mindset that embraces innovation and problem-solving in the context of technology integration. We employ second-order barriers (Ertmer, 1999) as a comparative lens to examine teachers' adoption of an automated feedback tool in a lower secondary school setting, while also examining a third-order barrier, the design thinking practices in the use of the automated feedback tool (Tsai & Chai, 2012).

2.1.1. First-Order Barriers

Given the pervasiveness of the use of technology in Norwegian schools, it would seem likely that schools in Norway have high levels of technology integration. Norway has made significant strides in addressing first-order barriers to technology integration in schools, ensuring technological infrastructure and capacity to support educational goals. This achievement reflects comprehensive policies and initiatives aimed at equipping schools with the necessary resources for digital learning environments. The 2017–2021 Action Plan for Digitalization in Primary and Secondary Education and Training marked a critical step in ensuring that students and staff have access to adequate digital infrastructure. Schools have increasingly adopted a one-to-one device model, beginning from first grade up to grade thirteen at upper secondary level, where nearly 100% of students had access to school-provided computers and these devices can be taken home (Gilje et al., 2020). This ensures that students and teachers across varying levels and subjects can access secure, purpose-driven technological devices tailored to their educational and administrative needs.

Additionally, the integration of high-speed internet into schools is a cornerstone of Norway's educational infrastructure. The 2003 Electronic Communications Act designates internet access as part of its universal service obligations, ensuring digital communications networks are accessible to all. Complementing this, the 2017–2021 digitalization plan emphasized providing students and staff with reliable internet access and high-quality digital equipment and content (Kunnskapsdepartementet, 2017). These measures have facilitated seamless connectivity, ensuring that schools remain equipped for pedagogical practices. This enables both students and teachers to have access to technology, where first-order barriers can be considered exceptionally low.

2.1.2. Second Order Barriers

While first-order barriers refer to external challenges such as insufficient resources, lack of infrastructure, and limited access to technology, second-order barriers are rooted in internal factors. These include teachers' beliefs, attitudes, skills, and pedagogical practices that influence how they integrate technology into their classrooms (Xie et al., 2021). Unlike first-order barriers, which can often be mitigated through policy changes or investments in resources, second-order barriers require addressing deeply ingrained beliefs and pedagogical habits. As such, they are considered pivotal in ensuring sustainable and meaningful technology integration. Research has shown that even when adequate technological resources are available, the successful integration of technology often hinges on overcoming second-order barriers (Durff & Carter, 2019; Ottenbreit-Leftwich et al., 2018; Prestridge, 2012). These barriers influence whether and how teachers adopt technology in ways that align with transformative educational goals

2.1.3. Third Order Barriers

First-order barriers address challenges associated with digital infrastructure, while second-order barriers focus on individual beliefs and practices. In comparison, third-order barriers examine systemic and design-level challenges that affect the teaching and learning process. The concept of third-order barriers is deeply tied to the iterative process of design thinking (Tsai & Chai, 2012). Within educational contexts, design thinking is exemplified by different constructs in which it involves a process in the creation of knowledge and practice by teachers when they adopt technology and its pedagogical opportunities (Makki et al., 2018). This process challenges teachers to not only adapt but also innovate in response to evolving technological and pedagogical demands. A strong understanding of technological pedagogical knowledge (TPK) (Mishra & Koehler, 2006) is essential for this stage, providing a deep insight into how teaching and learning can be transformed when digital technologies are utilized effectively. Tsai and Chai (2012) argue that without cultivating these skills, teachers may struggle to fully leverage the pedagogical affordances of technology or address systemic barriers effectively. Through the lens of third-order barriers, the focus shifts toward empowering teachers as designers who can navigate complexity, reimagine instructional practices, and innovate to enhance learning outcomes. To support the design thinking process, a structured approach to problem-solving is needed in educational settings. The process can be described in four stages (New South Wales Department of Education, 2021).

- Identify and Define (Understand the problem)
- Research and Plan (Research and ideate or brainstorm a solution)
- Produce and Implement (Create a draft or possible solution, get feedback)
- Test and Evaluate (Refine project, exhibit, and evaluate or reflect on the outcome)

2.2. Research Questions

While the use of AI-driven automated formative feedback in Norwegian secondary schools is gaining interest, only a limited number of studies have explored its adoption by learners (Bueie, 2024), and there is a lack of research addressing the design level changes that teachers make to integrate AI technology into their teaching practices and their beliefs in incorporating new technologies into the educational process. This study describes the experiences of Norwegian teachers when implementing AI-driven feedback while also documenting successes, lessons learned, and teachers' perceptions of continued technology use in the classroom. By examining both teachers' beliefs and the design thinking level changes that the teachers made, this research sheds light on practical strategies and policy considerations that can support the effective integration of AI-driven feedback in diverse educational settings. This study uses Ertmer's (1999) and Tsai and Chai's (2012) framework of second and third-order barriers, with specific research questions, as follows:

1. In what ways do teachers' beliefs shape their approach to integrating automated feedback into their classroom practices?
2. How do teachers redesign their pedagogical practices and implement design-level changes to integrate AI-driven automated feedback tools into their teaching?

3. Methodology

3.1. The Design of Our Study

This descriptive qualitative study was designed to describe teachers' beliefs and the design level changes made by the teachers. The descriptive qualitative design was selected as the methodological approach for this study as it enables us to provide a thorough, holistic, and rich summary of teachers' experiences in using the automated formative feedback. This approach remains closely aligned with the data, ensuring a direct and accurate representation of the participants' experiences (Hall & Liebenberg, 2024).

3.2. Essay Assessment Technology (EAT)

EAT is a design-based research (DBR) initiative (Brown, 1992) developed and designed in a 4-year DBR project called Artificial Intelligence Assessment for Learning (AI4AfL). It is a learning technology software developed to support formative assessment practices. The software technology uses AI technology to personalize and adapt the feedback to the needs of each learner and is being developed through three iterations. The software would offer (i) language feedback (spelling, grammar, and punctuation) (ii) content feedback, and (iii) structure and organizational feedback. EAT is designed to assist learners in their writing processes. It offers a range of functionalities, with the most relevant to this study being its focus on writing mechanics. The first prototype specifically addresses the syntactical aspects of writing, including grammar, spelling, and punctuation. EAT does not provide direct corrections; instead, it offers feedback that encourages improvement and provides guidance on how to revise the text. The feedback highlights problematic words or sentences, prompting students to make necessary changes. EAT fosters reflection and deeper learning by offering developmental feedback, helping students understand the underlying reasons for their errors, and promoting a better grasp of the writing process. By using the vast resources available online, we included relevant grammar rules and explanations as external links within the feedback provided. This enabled students to access additional information and deepen their understanding of grammatical concepts.

The first prototype was developed using an open-source language tool called the 'Language Tool', which enables the EAT to analyze texts and identify errors in grammar, punctuation, and spelling. Open-source language tools are widely used for natural language processing (NLP) tasks such as text classification, part-of-speech tagging, and

machine translation. This prototype was built prior to the emergence of generative AI. However, as the project progressed, generative AI was embedded into the second and third prototypes of EAT. The second prototype focuses on content, providing feedback on ideas, arguments, and the development of the student's message. The third prototype addresses organization, guiding students on the structure and flow of their writing. The current study explores the first prototype, which focuses on giving syntactical feedback (spelling, punctuation, and grammar).

While tools like Grammarly are commonly used for grammar correction, EAT was developed with specific pedagogical goals in mind. Grammarly mainly provides surface-level syntactical corrections (Ebadi et al., 2023). Unlike Grammarly, EAT emphasizes formative assessment and supports students' development across content, structure, and language. Additionally, Grammarly is not used in the Norwegian educational context due to concerns around General Data Protection Regulation (GDPR) compliance, making EAT a more suitable and legally appropriate alternative for educational institutions in this setting.

3.3. Informants, Context, and Settings

This study employed convenience sampling, a purposeful sampling technique (Merriam & Tisdell, 2015). The schools were selected based on their accessibility and willingness to participate, ensuring a feasible and efficient data collection process while still capturing relevant insights into the studied phenomena. This study draws from the data collected through the initial phase of the AI4AFL research project. Data for this study were collected in autumn 2022, during the first iteration of the EAT prototype. The informants in this study consisted of three lower secondary schools in a municipality in Eastern Norway. This study was approved by the Norwegian Agency for Shared Services for Education and Research, and all names used in the analysis are pseudonyms. Table 1 (see below) highlights the demographic information of the in-service teachers who participated in this study. Prior to the data collection, a workshop was organized so the teachers could familiarize themselves with EAT technology, and they were further encouraged to explore its features.

Table 1. Demographic Profile of the EFL Writing Teachers.

¹ Name	Faben	Laura	John
Class	Target Class	Target Class	Target Class
School	B	A	C
Education	General Teacher Education	International University	General Teacher Education
Years of teaching	4 years	21 years	10 years
Subjects that teachers are teaching	English	English	English
Gender	Male	Female	Male
Experience with automated feedback	No	No	No

¹ Note: All names are pseudonyms.

3.4. Data Collection

3.4.1. Individual Semi-Structured Interviews

The current study aimed to provide valuable insights into teachers' perceptions of using automated formative feedback in facilitating students' writing processes. Three participating teachers agreed to be interviewed. The interview was conducted face-to-face at the end of the process of writing. The interview questions were designed to elicit teachers' perceptions, experiences, and attitudes toward the use of automated formative feedback. The interviews, which were recorded and transcribed, had a duration ranging from 35 to 45 min. They followed a semi-structured format, as outlined in Kvale and Brinkmann

(2009), with open-ended topics and questions that allowed the interviewees to express their thoughts freely. These interviews were primarily conducted in Norwegian by the project team members.

3.4.2. Video Observations

We utilized the video data to cross-validate and corroborate the information provided by the teachers during their interviews. Video material presents a unique and invaluable opportunity for educational scholars and researchers to systematically examine authentic classroom settings. Utilizing video-recorded materials offers several advantages, such as enabling detailed and systematic observations of complex classroom situations and natural settings over extended periods (Klette, 2022). The design of video observations in this study involved the use of three cameras in each classroom. One camera was positioned to focus on the teacher, while the other two were directed towards the students. Additionally, three microphones were employed in this setup—one attached to the teacher and another two were fixed to the students' group to capture their discussions. This comprehensive recording approach, as demonstrated by (Fischer & Neumann, 2012) has the capability to capture both the actions and viewpoints of teachers and students in a single recording, the ability to break down teaching practices into smaller components, and the option to approach the same recorded teaching segment from various analytical perspectives.

Once the video recordings were exported, we examined the video repeatedly, attempting to describe objectively what was happening as completely as possible without reference to preconceived categories or prejudices. We confine ourselves to pointing out what is visible or audible on the recordings. Klette and Blikstad-Balas (2018) highlight the synergy of video data, which enables the recording, reviewing, analysis, and synthesis of diverse instructional practices. This enhances the overall trustworthiness of observations, not only because the initial observer can revisit the same segments multiple times, but also because it enables traditional quality assurance methods like reliability testing, member checking, and secondary analyses in novel ways. Video data promote transparency and clarity, making codes and coding systems the subjects of collaborative discussions and validation, encompassing the development and testing of the different codes for validity and reliability. The total hours used in the video recording for Laura is 8 h and 25 min, Faben is 7 h 42 min, and John is 7 h and 30 min.

3.5. Data Analysis and Trustworthiness

The interview data were transcribed verbatim by the researchers. At the initial phase, a transcription software, Microsoft Word online, that automatically transcribes audio to text was used. This process allowed for easy editing. This software was especially useful for verbatim translations, ensuring that the meaning of the original Norwegian responses was preserved. After the software-generated transcription, the researcher listened to the recording and edited the words spoken to ensure an accurate representation of the teachers' responses. The researcher then translated the Norwegian verbatim text into English. The researcher made efforts to accurately translate the Norwegian transcripts into English, while still emphasizing to keep the original meaning as conveyed in Norwegian. We screened the transcription to identify common themes emerging from teachers' responses. The data were then initially coded manually. The coding was performed manually by the researcher, following a deductive approach to develop codes and themes directly from the data. The researcher maintained detailed notes throughout the coding process to ensure transparency and consistency. The researcher utilized a thematic analysis approach, identifying recurring patterns and key themes related to the teachers' perceptions and experiences. Initial analysis was conducted by the first author, with the second author

independently reviewing the results to ensure internal validity. Any discrepancies were resolved through discussions between both authors. In the second phase, codes were refined. The findings are thus based on the triangulation of video data and interview data. However, in line with Mathison (1988), our aim was not limited to triangulation for validity checks, but also to elaborate on convergence, contradiction, and inconsistency in line with the purpose and research questions of this study. Credibility was established through constant interaction with data and the use of researcher triangulation (Donkoh & Mensah, 2023; Lincoln et al., 1985). Regular peer debriefings ensured that the investigators stayed informed about the research process and continually evaluated the preliminary findings and interpretations of the data.

4. Results

In exploring the integration of an AI-driven automated formative feedback tool, we hope to explore the teachers' use and perceptions of AI-based automated feedback. Through a comprehensive examination of teacher interviews and video observations, we aim to offer insights into teachers' beliefs and the design level changes that they made in their teaching. The results are presented according to the research questions.

4.1. Research Question 1: In What Ways Do Teachers' Beliefs Shape Their Approach to Integrate Automated Feedback into Their Classroom Practices?

4.1.1. Teachers' Beliefs About Technology

All the teachers in this study had no prior experience with using an automated feedback tool. The teachers emphasized the importance of becoming familiar with the tool before feeling confident enough to integrate it into their teaching. As Faben explained, *I had to familiarize myself with it first and see how it worked. . . . at the beginning. So I took some time. But. . . you know what. . . I. . . I used it.* This initial hesitation gave way to active use, as he began incorporating the tool. *I walked around and said, 'Look at this mistake here. You have grammatical errors here. Shall we search a bit in the text? See now. It says you're missing some commas. Shall we search together in the text?'* This illustrates a shift from uncertainty to a more exploratory and student-centered use of the tool, where the teacher guides students in interpreting feedback and reflecting on their writing. Teachers were also helping students to interpret the output from the automated feedback. Automated feedback increases the teachers' desire to help students understand the feedback that they have received. It highlights how belief in technology's usefulness may grow through direct experimentation. With minimal familiarity on how to use the tool, the teacher was very optimistic and viewed the tool as effective in helping to achieve the pedagogical objectives. We observed that he helped students and facilitated their understanding and interpretation of feedback. The teacher was actively engaging in the feedback process with the students.

4.1.2. Teachers' Beliefs About Students' Role

The teachers in this study believed in student-centered learning, where learners are active participants. Students are expected to guide and give each other feedback (peer feedback) and engage with the content. Through such practices, students are seen as capable of constructing knowledge through dialogue. Faben articulated that

Yes, the students were supposed to guide. . . or give feedback to each other. So I decided that they should give their PCs to each other and read the text first, and then they should talk. And what happened then was that they gave feedback on what they needed to improve in the text. That could be things like language, structure. . . uh. . . grammar. . . depending on the differences in the groups' levels. Of course, if you have a group with lower-level differences than one with higher-level differences, the feedback will also differ, I think. So

it worked well. I was very careful that they should give constructive feedback—not just be nice to each other, as they usually are. So it improved. So overall, I think it was a very successful part. It could have been much better, of course. (Fabien)

Instead of just being a passive recipient of information, the teacher believes that students should take ownership of their own learning and position themselves as independent thinkers. Fabien held a positive view of his students' engagement with the feedback provided by the automated system and the collaboration practices with their peers. Additionally, the teacher noted that the students responded quickly to the feedback, indicating a high level of motivation and willingness to participate. This observation suggests that the students were effectively engaged and found the feedback process beneficial. However, the teacher also observed that some students exhibited uncertainty, which could be attributed to limited training on how to effectively utilize the feedback from the tool. This indicates a need for more comprehensive instruction on how to interpret and apply feedback, to ensure all students can benefit from the automated system. Moreover, the teacher observed that students initially struggled to grasp the feedback process but noted that their understanding improved after several rounds of feedback. This progression highlights the importance of repeated exposure to the feedback system, allowing students to become more familiar and comfortable with the process over time.

I think it went well. I thought it was nice to see that most of them got started quickly. I was not sure because 40 min is not long. Many managed that, and I thought that was nice to see. It was a bit concerning that some of them locked up at the beginning, and they never got started. And a couple of students achieved that, but then they got started, and yes, it was perhaps the first time they received feedback, so it went very well. Then maybe it was a bit different the third time or the second time they got feedback. That, I do not know. Maybe they were a bit tired or something? (John)

4.1.3. Teachers' Pedagogical Beliefs (Task Completion)

Another aspect that is apparent in this study is teachers' beliefs about task completion. The experienced teacher (21 years in teaching) in this study focuses heavily on task completion and displays concern about students not completing the task within the time frame. The teacher believed that the amount of feedback overwhelmed her students. The teacher suggested reducing the time for group discussion to enable students to write. In using the automated feedback tool, we found that the teacher was more concerned about completing the task than engaging in the feedback from the automated system. The teacher noticed that students were stressed about not completing their stories, which they perceived as critical for their grades. This stress prompted the teacher to reflect on her teaching practice and thus suggested that in the future she would reduce the time for group discussions. The teacher, who is accustomed to established routines, felt that the time allocated for the group discussions was excessively long. This suggests that there may be a need to adjust the duration of these sessions to better align with the teacher's belief of optimal time management and efficiency. Recognizing the importance of peer discussions for understanding feedback, the teacher nevertheless felt that adjusting the session by reducing discussion time would allow more time for actual writing, which the teacher deemed a natural and productive shift.

Because they were stressed about not having finished their stories, umm, they thought it was important for their grades to complete the story and that they had to spend a lot of time explaining to the others in the group that they had a little mistake with 'liten i' [small 'i'] for example. So, I might have reduced the time for discussions a bit. Of course, I understand that it's important for them to discuss, but when everyone is satisfied [light

laughter] and feels done with discussing the rules, then I think it's natural to spend the rest of the time writing. (Laura)

4.2. Research Question 2: How Do Teachers Redesign Their Pedagogical Practices and Implement Design-Level Changes to Integrate AI-Driven Automated Feedback Tools into Their Teaching?

We have identified an iterative design thinking process undertaken by teachers as they adapted their practices for AI integration. As outlined in Table 2, this process involved addressing two dimensions, which can be broadly categorized into two main themes: pedagogical issues and learning issues.

Table 2. Key themes in relation to design thinking.

Issues	Sub-Issues	Descriptions	Quotations
Pedagogical	Instructional strategy	Navigating the interface	There were some students who clicked through a bit too quickly, who had submitted the text and then we had to make an update to go back a few steps in the writing process, and then many had lost much of the text, and that was not so good. No, exactly, but when that happened, they asked you, and then you felt that you needed to have that knowledge about technology to help the students out of it.
	Knowledge on how to promote independent learners	Resistance to process writing and feedback due to time constraints	It was a bit concerning that some of them locked up at the beginning, and they never got started.
	Grouping	Unable to generate quality discussions due to same academic level	Umm, and then maybe the organization of the groups, because now we put together groups with similar, the same academic level. And I think I would organize the groups a bit differently next time to have more variation in the academic level. Because—umm, the strongest ones grasp all the rules right away, no problem, while it can be difficult if you have some weaker students at the same level
Learning	Cognitively overloaded	Feedback was overwhelming for students	There was one who managed to write 38 words. Struggled a long time with those 38 words. Well, he did not get—he did not have 80 errors, but he did—yes on 38 words he had about 16 errors.

4.2.1. Pedagogical Issues

The design thinking process in this study aligns with commonly accepted models that involve identifying and defining problems, researching and planning, producing and implementing, and finally testing and evaluating (New South Wales Department of Education, 2021). These stages provide a conceptual lens through which we analyzed teachers' experiences with the automated feedback tool. Here are three sub-issues we found in our study. The first sub-issue is instructional strategy. In the identifying and defining

problem phase, the teacher noticed the challenges students face while using the automated feedback system. For example, the teacher noticed that the students had issues navigating the interface. In the process of using the interface, the student had lost half of the text. This can be problematic, as evidenced by instances where teachers find themselves needing to intervene when students click through the process too quickly and lose substantial portions of their text. Such situations highlight the need for teachers to possess a robust understanding of technology to provide timely and effective support. Here, the teacher quickly brainstormed for a solution. In the research and plan phase, the teacher had not previously considered the backup strategy, but was able to come up with a solution where students were encouraged to save it in Microsoft Word first instead of directly typing into the EAT system. This quick response demonstrates adaptive planning and a willingness to co-construct a solution, which is part of a design thinking process.

In this second sub-issue, the teachers demonstrated a critical ability to identify and address students' delay in getting started to process writing. The teachers recognized that some students hesitated to engage fully with the iterative writing process, often requiring additional support to get started or to use the feedback effectively. Moving to the research and plan phase, teachers responded creatively to these problems. By noticing the patterns of disengagement or hesitation early on, teachers were able to intervene strategically by providing students with targeted support, ensuring that students could move forward. Their understanding of these challenges allowed them to adapt their instructional strategies to better support students, balancing the autonomy intended by the automated feedback tool with guided assistance when necessary.

The issue of student grouping was another key area where teachers engaged in a design thinking process. This aligns particularly well with the phases of identify and define, plan, implement, and evaluate. Teachers could identify the problem of grouping students by similar academic level, which limited the quality of peer discussions, as it reduced the potential for knowledge-sharing and varied perspectives. Next, in the 'Plan' stage, the teacher proposes a solution. The teacher felt the need to organize groups with mixed academic levels in future sessions. This suggestion demonstrates both empathy for student learning needs and a proactive mindset, where the teacher considers how peer dynamics can scaffold understanding, especially for weaker students. Though the 'Implement' stage is not directly evidenced in the quote, the teacher's intention to revise groupings in future iterations of the activity suggests an ongoing, reflective process typical of design thinking. Finally, this feeds into the 'Evaluate' phase, as the teacher is already evaluating the impact of past grouping strategies and using this insight to improve future practice.

4.2.2. Learning Issues

When the automated system generated a large volume of feedback, teachers expressed concerns about the potential for cognitive overload among students. Using the design thinking model, we can trace how teachers engage with problem identification, planning, implementation, and evaluation. In this situation, in the 'Identify and Define' phase, teachers observed that students, particularly weaker learners, felt overwhelmed by the amount of feedback they received. This cognitive overload hindered students' ability to process and act on the feedback meaningfully. To mitigate this (plan phase), the teacher's strategy of asking the learners to prioritize the feedback approach shows the teacher's ability to solve and provide a solution immediately. By highlighting the most critical feedback that the students would have to address first, the teachers reduced the anxiety in the weaker learners.

5. Discussion and Conclusions

Although it was the teacher's first attempt to integrate the tool into their teaching, the teachers in this study demonstrated a beginning understanding of the theoretical underpinnings of the automated feedback tool. This could be attributed to their openness to new methodologies. Their enthusiasm to adopt the tool aligns with findings from prior research, Karolčík and Marková (2023), which suggests that teachers are more likely to embrace innovative practices as part of their professional growth. This could probably be because teachers mainly think of technology as a new way of supporting and innovating teaching. The ability to assist automated feedback effectively requires a blend of pedagogical knowledge and technological skills from the teacher. In this perspective, we found that the teachers were able to nurture and provide positive classroom support to the learners. Besides, teachers recognized the importance of facilitating students' active role in learning. Teachers were seen promoting a culture of two-way dialogue with the students to help learners interpret the output from the tool. Teachers had better control of the learning due to the individualised personalized feedback and therefore could assist learners who needed more help and support learners in interpreting the feedback. Additionally, the automated feedback tool not only complements the traditional instructional methods but also successfully cultivates a reflective and collaborative learning culture. The teacher's role was not only in guiding and mentoring the learning practices, but also viewed as a scaffolding process that helps learners to develop their agency.

Besides, teachers in this study saw the potential of the tool to enhance teaching without overshadowing established practices. By reinforcing their existing strategies with technology, these teachers demonstrated the ability to bridge traditional and innovative approaches effectively. Their belief that group discussions should be shortened to allow students more time to write reflects a pragmatic approach focused on time management and task execution. This aligns with previous research indicating that teachers often view innovations through the lens of classroom efficiency and student outcomes (Abel et al., 2022). Although teachers are very positive towards technology integration and express their interest in using automated feedback, they still hold on to the belief that technology can affect lesson time and flow (Bećirović, 2023). This resonates with prior research suggesting that teachers develop positive beliefs when they perceive it as useful and recognize the value of the new technology (Bowman et al., 2020; Xie et al., 2021).

Another aspect that was prevalent in this study is that teachers revealed that their intentions to utilize technology were influenced by their exposure to design thinking. The teachers' proactive identification of students' problems highlights their critical role in facilitating the effective use of automated feedback systems. Their capacity to observe, analyze, and address resistance to process writing ensures that such tools are integrated in ways that align with students' learning needs and encourage progress toward greater independence. The teachers encounter a range of obstacles that test their adaptability, digital proficiency, and pedagogical strategies. These challenges highlight the complexity of effectively merging traditional teaching methods with technology to meet the diverse needs of learners. However, they were able to solve complex problems and came up with solutions. The teachers in this study not only provided solutions to immediate challenges but also had the intention to develop long-term strategies for integrating technology in meaningful ways. This aligns with findings by Blundell (2024), who argues that teachers can embrace the complexities of teaching-learning practice and are able to move beyond superficial technology use and develop sustainable, pedagogically sound practices. Furthermore, Bartlett (2021) highlights that such intentional, design thinking practices lead to teachers expanding their actions, embracing ambiguity, as well as being optimistic will eventually lead to improved student outcomes.

This study extends the current literature on teachers' beliefs and on design thinking. This paper, therefore, concludes that the successful integration of AI-based automated formative feedback demands a transformation not only in curriculum and pedagogy but also in teachers' beliefs, the way teachers think and behave. For AI-based automated feedback tools to be effectively integrated into classrooms, teachers must understand how they perceive their role, how they approach teaching, and how they engage with new technologies. This transformation is critical in ensuring that the potential of AI-based automated feedback is fully maximized.

6. Implications of This Study

There are several implications from this study. First, teachers need targeted professional development courses. Specifically, teachers need guidelines and support when using new technology. Teachers often face challenges in facilitating meaningful interactions when students have similar abilities, which can limit the potential for peer learning. In contrast, mixed-ability groups can enhance classroom dynamics, as students of varying strengths support each other through collaboration. Educators could adopt strategies that encourage interaction among diverse groups, fostering an inclusive learning environment where all students can contribute. When they have low knowledge of how to use the tool, much of their time will be lost in trying to figure out the functionality of the tool. This, in turn, could affect the learning process. When teachers possess a limited understanding of how to utilize new applications, a significant portion of instructional time may inadvertently be dedicated to navigating and deciphering the functionalities of these tools. This scenario not only detracts from the quality of instruction but also impedes the integration of technology into the curriculum. We strongly encourage that professional development programs incorporate design thinking principles to help teachers navigate the complexities of technology integration. Furthermore, teacher education programs should emphasize the development of adaptive, design-focused mindsets, equipping educators to manage not only technical and logistical challenges but also the deeper pedagogical and cognitive barriers that arise in today's digital learning environments.

Second, teachers need awareness of how to promote independent learners in each student's academic needs, and the skill to draw on appropriate tools in ways that support students in each of these areas when responding to increasingly diverse student cohorts. Although we know that personalized learning experiences are essential in promoting learners to be independent, teachers who have a low level of knowledge on how to develop, support, and promote autonomous learning would encounter difficulty when they see learners who are struggling.

Third, higher learning institutions should not only focus on teaching future teachers on how to teach with technology, but teacher preparation should encourage teachers' reflections about beliefs and possible beliefs of change, which is not about fixing beliefs but helping teachers to see. While believing in the value of technology is a necessary precondition, it does not guarantee its use in the classroom. Preservice teachers must engage in authentic classroom situations that prompt them to consider and confront their beliefs regarding technology as an instructional tool. The strategic placement of preservice teacher candidates with mentors who are enthusiastic about the use of technology may facilitate the translation of the preservice teachers' theoretical commitments into practice while overcoming their own barriers.

7. Limitations and Future Research

Several limitations are apparent in this study. Firstly, the intervention period was relatively short (one school day), and data were collected for only one cycle of process

writing. This limited timeframe may have restricted our ability to observe how teachers modify their instructional strategies and to gain a better understanding of their facilitative role in supporting student learning. A longer observation period, such as across the academic year, would have allowed for a deeper exploration of how the tool is integrated into teaching practices over time. Longitudinal studies could provide more comprehensive insights into the long-term impact of such tools on both teaching practices and student outcomes.

Secondly, all observations were scheduled in advance, which may have led some teachers to adjust their preparations with the students, anticipating the observations. This preparation could have influenced the patterns of tool usage observed during this study. To address this limitation, future studies could incorporate a mix of pre-scheduled and randomly occurring observations, which would allow for a more naturalistic exploration of tool usage in everyday teaching contexts.

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Article

Online Physical Education: A Mixed-Methods Study of the Health Perceptions and Professional Effectiveness of Physical Education Teachers

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Abstract: The professional efficacy and health perceptions of physical education (PE) teachers, along with school characteristics, significantly impact their ability to navigate remote teaching challenges, maintain student engagement, and deliver inclusive, effective instruction. Remote teaching has become a widespread instructional method, particularly during the COVID-19 pandemic, but it also presents unique challenges for PE educators, requiring specialized pedagogical strategies and technological adaptation. This study aims to evaluate the professional efficacy, health perceptions, and pedagogical approaches of PE teachers in the context of remote teaching. Employing an explanatory sequential mixed-methods design, we conducted a cross-sectional web survey (N = 757) followed by in-depth interviews (N = 15). Participants were selected from a list provided by the Israeli Ministry of Education, with inclusion criteria requiring at least one year of PE teaching experience. Quantitative data analysis included chi-square tests, *t*-tests, Pearson correlation, and multiple regression analyses, while qualitative data were analyzed using conventional content analysis to identify emergent themes. Our analysis reveals that female with higher levels of education, research skills, and advanced knowledge in teaching technologies exhibit significantly greater teaching professional efficacy in remote settings. These findings suggest that educational institutions should develop tailored training programs that account for gender and educational differences, thereby equipping PE teachers with the necessary skills to excel in remote teaching environments. This proactive approach will better prepare PE educators to navigate future challenges in the ever-evolving landscape of education.

Keywords: physical education; remote teaching; teacher efficacy; technology integration; emergency education

1. Introduction

Remote teaching has become a widely adopted mode of instruction, particularly in response to the COVID-19 pandemic (Heng & Sol, 2021; Glaser et al., 2022). However, beyond medical emergencies, various other circumstances can necessitate school closures, including natural disasters (e.g., severe weather, fires), technological crises (e.g., hazardous material accidents), and human-made emergencies (e.g., wars, active shooter situations). Against this backdrop, it is critical to examine the factors that influence the effectiveness of remote teaching, especially for physical education (PE) teachers (Mercier et al., 2021). Remote teaching—often called online learning—presents educators with unique opportunities and distinct challenges (Leech et al., 2020). It enables students to engage in learning activities without being physically present, facilitates self-paced learning, and leverages digital resources to accommodate diverse learning styles. However, delivering PE remotely requires specialized skills, strategies, and support systems (Mercier et al., 2021). PE teachers face particular challenges when teaching in an online setting. These include difficulties with curriculum planning, assessing student performance, ensuring accountability, and maintaining safety—all of which can significantly impact the quality of remote PE instruction and learning outcomes (Gobbi et al., 2021; Giladi et al., 2021).

Among the factors that influence PE teachers' remote teaching ability is their self-efficacy. Self-efficacy and work engagement were relevant to mastering the challenges of PE teaching during the pandemic and beyond (Gobbi et al., 2021). Bandura (1986) defined self-efficacy as "a person's judgment of his or her abilities to organize and execute courses of action necessary to achieve designated types of performances" (Giladi et al., 2021). Teacher self-efficacy is the belief in one's ability to teach and engage students in a learning environment effectively. Teachers with a strong belief in their teaching capabilities will achieve higher goals. In contrast, those with a weak belief in their capabilities grapple with a fear of failure (Hussain et al., 2022). Educators with high levels of self-efficacy are more likely to accept challenges and implement effective teaching strategies while those with low levels of self-efficacy are more likely to feel ineffective and dissatisfied with online learning (Fauzi & Sastra Khusuma, 2020). Professional efficacy, which encompasses the confidence and competence of PE teachers in delivering quality PE lessons through online platforms, has a crucial role in the effectiveness of remote teaching practices and student learning outcomes (Cardullo et al., 2021).

The integration of technology into physical education brings both opportunities and challenges and requires educators to adapt their pedagogical approaches and embrace new digital tools (Wallace et al., 2022). The rise in online physical education has been further accelerated by recent global events such as the COVID-19 pandemic, which necessitated the rapid transition to remote learning environments (Chiu et al., 2021). During this time, many teachers have experienced both difficulties and successes, highlighting the importance of understanding these experiences to improve the online implementation of physical education programs (Daw-as & Magat, 2022). The sudden shift to online learning has forced teachers to re-evaluate their teaching methods and adapt to the unique demands of the digital world (Sato et al., 2023; Zhang et al., 2025).

One of the biggest challenges in online physical education is maintaining student engagement and motivation (Mohnsen, 2012). To promote meaningful engagement in online environments, teachers must utilize various strategies and instructional practices that encourage active participation and collaboration (McKeithan et al., 2021). The success of online physical education depends on teachers' ability to use technology effectively to deliver engaging and interactive learning experiences. Physical education teachers need to improve their digital teaching skills. This includes technical knowledge, a deep understanding of the pedagogical potential of digital tools, and the ability to analyze and respond to student

feedback (Zhang et al., 2025). Establishing clear communication channels and providing timely feedback are essential components for fostering connection and support in virtual learning environments (Sato et al., 2023). To improve their effectiveness in distance teaching, PE teachers should actively work with available technological resources and acquire skills in using digital platforms that support communication, collaboration, and assessment processes. The integration of information and communication technologies (ICTs) into teaching practice requires that teachers are provided with meaningful opportunities for professional development in digital pedagogy (Rakisheva & Witt, 2022). With the increasing prevalence of virtual learning environments, students are demonstrating higher levels of engagement and immersion in relevant online learning experiences (Dang et al., 2024).

Health perception is another key factor which affects PE teachers' job performance; PE teachers' health perceptions also have a significant role in their ability to effectively perform their job duties (Bartholomew et al., 2014). Teacher health and well-being are vital to creating a conducive learning environment and positively impacting student experiences (Benevene et al., 2020). Health perception refers to how teachers subjectively evaluate their overall health status and encompasses physical, mental, and emotional well-being (Ben Amotz et al., 2022). The health and well-being of teachers, in general and especially during emergencies, play a crucial role in their job performance (Centeio et al., 2021; Whalen, 2020). Teachers who experience high levels of stress or face physical or mental health challenges may develop a negative perception of their health. This negative health perception can harm their ability to carry out their teaching responsibilities effectively. Conversely, when teachers perceive themselves as healthy, they are more likely to possess high levels of self-efficacy and be more energetic, engaged, and effective while teaching (Lee et al., 2024; Su et al., 2022).

In addition to teachers' professional efficacy and health perception, various school characteristics can influence the effectiveness of remote teaching among PE teachers (Jeong & So, 2020). Factors such as the type of school, teaching experience, and school management practices can significantly impact teachers' confidence and competence in delivering remote PE lessons (Hussain et al., 2022). Demographic parameters, such as gender and education level, can also have implications for teachers in the remote teaching of PE (Bortoleto et al., 2020). Creating an inclusive and supportive environment in remote teaching is essential, as PE teachers consider their students' diverse needs, interests, and preferences, and tailor activities, learning objectives, feedback, and assessment methods accordingly (Monteiro et al., 2021).

In line with the above, using a mixed-methods approach, the current study aimed to evaluate the professional efficacy, health perceptions, and pedagogical approaches of PE teachers in the context of remote teaching.

This study aimed to evaluate the professional efficacy, health perceptions, and pedagogical approaches of physical education (PE) teachers in the context of remote teaching, by addressing the following research questions: (1) What are the levels of remote teaching professional efficacy and health perception among PE teachers during the COVID-19 pandemic? (2) Are there significant differences in professional efficacy based on teachers' demographic, educational, and school characteristics? (3) What is the relationship between PE teachers' health perceptions and their professional efficacy in remote teaching? (4) What factors predict higher levels of professional efficacy in remote instruction? (5) How do PE teachers describe their experiences, challenges, and successes with remote teaching?

2. Materials and Methods

This section describes the methodological framework of this study, including the research design, participant selection, data collection procedures, and ethical considerations. We used a mixed-methods approach combining a quantitative cross-sectional survey with qualitative interviews to gain a comprehensive understanding of PE teachers' experiences of distance education.

The data were collected during the COVID-19 pandemic, ensuring relevance to real-world pedagogical challenges. This study adhered to strict ethical standards, including informed consent and anonymity, to ensure the integrity and reliability of the results.

2.1. Study Design

We employed an explanatory sequential mixed-methods design, consisting of a quantitative cross-sectional survey followed by in-depth qualitative interviews. This design allowed for a comprehensive exploration of physical education teachers' experiences with remote teaching, combining the strengths of both quantitative and qualitative approaches. The research design and data collection procedures adhered to high reporting standards for mixed-methods studies (Creswell & Plano Clark, 2017; O'Cathain et al., 2008).

2.2. Participants and Procedure

Data were collected in 2020 during the COVID-19 pandemic, when school teaching was conducted remotely. A survey questionnaire measuring professional efficacy was distributed to potential participants. We employed a convenience sampling approach using a list of physical education (PE) teachers provided by the Israeli Ministry of Education.

The sampling frame consisted of 800 PE teachers randomly selected from regular and special education schools across Israel. Inclusion criteria required participants to have at least one year of PE teaching experience and to provide informed consent. The exclusion criterion was PE teachers with less than one year of teaching experience.

The final study population comprised 757 PE teachers, of whom 65.7% were female. The mean age was 46.96 ± 10.20 years, with an average of 17.37 ± 11.09 years of teaching experience. The majority taught at the elementary school level ($n = 392$, 51.5%), and the most common school type was the general (secular Jewish) public school system ($n = 537$, 70.5%).

A letter was sent to the selected teachers, explaining this study's objectives and the significance of their participation. The participating teachers completed online questionnaires between May and June 2020, and responses were collected anonymously by the lead researcher.

We then approached 30 physical education (PE) educators from our sampling frame within the Ministry of Education, of whom 15 agreed to participate in a qualitative interview. Two college students from the university's Department of Social Sciences served as research assistants and conducted semi-structured interviews with the 15 PE teachers via the Zoom platform.

The inclusion criteria were as follows: Minimum teaching experience: participants had to have at least one year of experience in teaching physical education. Selection process: The Israeli Ministry of Education provided a list of eligible physical education teachers and 30 teachers were initially contacted. Of these, 15 agreed to participate. Consideration of diversity: Care was taken to ensure that the participants were as diverse as possible in terms of gender, school type (public, religious, special school), and grade level (elementary, middle school, and high school). Experience with distance learning: Participants had experience with distance learning during the COVID-19 pandemic, ensuring relevant insights into the focus of this study.

Before the interviews, participants were explicitly informed that any information they considered confidential would not be documented or recorded. Additionally, they were given the option to decline answering any questions that made them uncomfortable. The audio recordings of the interviews were subsequently transcribed to facilitate data analysis.

This study received approval from the Ariel University Institutional Review Board (IRB) to ensure compliance with ethical guidelines. Participants were provided with comprehensive information about the research objectives and voluntarily agreed to participate.

Before completing the survey, participants signed an informed consent form, confirming their voluntary participation. They were assured of their right to withdraw from this

study at any time, that their responses would remain confidential, and that the survey data would be analyzed anonymously.

2.3. Independent Variables

Socio-demographic variables included sex (female, male), age, family status (single, in a relationship, divorced, widowed), religion (Jewish, Muslim, Christian, Druze, other), level of religiosity (secular, traditional, religious; measured by self-definition), education level (senior teacher, bachelor's degree, master's degree, doctoral degree), and years of seniority at the school.

Teaching-related variables included the religious sector affiliation of the public school, as designated by the Ministry of Education (secular Jewish, Orthodox Jewish, Arab, Druze), and school type (elementary, middle, high school).

The policy regarding remote teaching was assessed using items from the European Federation of Adapted Physical Activity (EUFAPA) survey. One item stated: "In my workplace, there are clear guidelines regarding the usage of remote teaching and remote communication". Responses were recorded on a five-point Likert scale ranging from 1 (completely disagree) to 5 (strongly agree).

Remote teaching media usage was also measured using items from the EUFAPA survey. Sample questions included: "What media do you use daily to communicate with students and colleagues?" and "What media do you use for remote teaching in PE lessons?" In the current study, the internal reliability of the scale was determined to be good, with a Cronbach's alpha coefficient of 0.85.

2.4. Dependent Variables

Health perception—Participants' health was self-rated in response to the following question: "How would you describe your health during the past year?" Answers were scored on a 6-point scale ranging from 1 (poor) to 6 (excellent). The self-rated scale is a standardized indicator widely used in diverse health research studies (Wu et al., 2021).

Professional efficacy—The questionnaire consists of 11 items (for example: "I must succeed in conveying content in physical education via distance learning") on a 5-point Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree". Higher scores indicate greater self-efficacy in distance learning. The scores were used as both continuous and categorical variables (those with a score below and above the median score of 39). In addition, participants who scored 1 ("strongly disagree") to 3 ("average") were categorized as having low to average professional efficacy, while those who scored 4 ("agree") and 5 ("strongly agree") were categorized as having high professional efficacy. The questionnaire has been validated in several studies and has both content and predictive validity (Chen et al., 2001). In the present study, the scale demonstrated good internal reliability with a Cronbach's alpha coefficient of 0.83.

2.5. Statistical Analysis

In the quantitative section of this study, statistical analyses were performed using two software programs. The Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM, Chicago, IL, USA) was used for Cronbach's alpha calculations, descriptive statistics, chi-square (χ^2) tests, independent *t*-tests, and Pearson correlation analyses. MedCalc statistical software was employed for multiple regression analysis.

2.5.1. Study Participants', Demographic, Teaching, and School Characteristics

Demographic, teaching, and school characteristics were described using descriptive statistics (n, percentage, mean, and standard deviations). Differences in prevalence of the categorical variables were examined using chi-squared tests.

2.5.2. Teachers' Remote Teaching Professional Efficacy and Health Perception Differences

The prevalence of teachers with poor-to-average professional efficacy and high efficacy on each of the scale's 11 items was calculated and compared using chi-square tests. In addition, the association between professional efficacy and health perception was examined using Pearson's correlation. In the next step, differences in remote teaching professional efficacy between participants with different perceptions of their own health status were compared using One-Way Analysis of Variance with Tukey–Kramer post hoc tests. These results are also presented using a box-plot figure.

2.5.3. Factors Influencing Variations Between Participants with Different Levels of Remote Teaching Professional Efficacy

The Pearson correlation coefficient examined the associations between participants' professional efficacy and continuous variables (age and seniority). The mean scores of the professional efficacy of participants with different characteristics were then compared using a *t*-test (dichotomous categorical outcomes) or One-Way Analysis of Variance (three- and four-level categorical outcomes). In the One-Way Analysis of Variance, the Tukey–Kramer post hoc test was used.

2.5.4. Factors Predicting Remote Teaching Professional Efficacy

A multiple binary logistic regression was performed to determine how basic demographic, teaching, and school characteristics can predict binary categorical variables, namely, presenting below- or above-median professional efficacy. In this respect, the dependent variables were coded as 0 (i.e., presenting below-median professional efficacy) and 1 (i.e., presenting above-median professional efficacy). For continuous variables, only variables whose correlation with teachers' professional efficacy were statistically significant were entered into the model. Similarly, for categorical variables, only variables whose statistically significant ability to differentiate between participants with different levels of professional efficacy were entered into the model.

2.5.5. Power Analysis

Post hoc power analysis for the regression model was conducted using the mean remote teaching professional efficacy of individuals with different demographic, teaching, and school characteristics. The alpha error probability was set at 0.05 for the power analysis calculation. Additionally, effect sizes between groups were calculated to assess the magnitude of differences. Cohen's *d* was used to measure effect size, calculated by dividing the difference between group means by the pooled standard deviation.

All the statistical analyses, except for power analysis, was performed using SPSS Statistics for Windows, version 29 (SPSS Inc., Chicago, IL, USA), where the level of significance was set to $p < 0.05$ (2-tailed). Power analysis was calculated using G*Power software 3.1.9.4.

The qualitative analysis of the interviews was performed using Microsoft Excel software to aid in conducting conventional content analysis, following the approach outlined by Hsieh and Shannon (Hsieh & Shannon, 2005). This method facilitated data categorization and examination. The two authors independently coded the text responses, identifying keywords, labeling high-frequency words, and categorizing them. Through continuous comparative analysis and revisiting the categories, themes specific to PE teachers emerged. To ensure rigor, a third investigator reviewed and coded the text independently, and any discrepancies among the team were resolved through a final discussion session (Popping, 2015).

2.5.6. Qualitative Data Were Managed and Analyzed Using NVivo, Version 11

The entire dataset, including the complete responses of all participants, was coded by one author (Castleberry & Nolen, 2018). During coding, content relevant to the research

aims was specifically identified. A descriptive phenomenological approach was employed to ensure the accurate representation of the data analysis results.

The coded data corresponding to the quantitative variables in the measures, including the Perceived Stress Scale (PSS-10) and the Post-Traumatic Stress Disorder Checklist (PCL-5), were extracted and compared between the two groups. The teachers' extracted narratives were translated into English.

3. Results

This section presents the results of this study in line with the research objectives. The quantitative findings focus on identifying factors that influence PE teachers' professional effectiveness in distance education, examining differences in effectiveness based on demographic variables, and exploring the relationship between professional effectiveness and perceptions of health. The qualitative findings provide deeper insights into the experiences and challenges physical education teachers face in transitioning to distance education and highlight issues such as adaptability, preparation, and gender differences in professional effectiveness. Taken together, these findings contribute to a comprehensive understanding of the factors that shape effective distance PE teaching and inform strategies to support PE teachers in future online teaching scenarios.

3.1. Quantitative Results

3.1.1. Study Participants', Demographic, Teaching, and School Characteristics

Of the 757 PE teachers participating in this study, 65.7% were female, and the mean age was 46.96 ± 10.20 . The mean number of years the participants had been teaching was 17.37 ± 11.09 years; most taught at the elementary school level ($n = 392$, 51.5% of the sample). The most prevalent school type was the general (secular Jewish) public school system ($n = 537$, 70.5% of the sample). For additional information, refer to Table 1.

Table 1. Study participants' demographic, teaching, and school characteristics (N = 757).

Characteristics			Mean (SD) Or N (%)
Demographic characteristics	Sex: n (%)	Females	500.00 (65.7)
		Males	261.0 (34.2)
	Age: mean (SD)		46.96 (10.2)
	Family status: n (%)	Single	88.0 (11.5)
		In a relationship	613.0 (80.5)
		Divorced/widowed	60.0 (7.8)
	Religion: n (%)	Jewish	647.0 (85.0)
		Non-Jewish	114.0 (14.9)
Education: n (%)	Senior teacher + bachelor's degree	429.0 (56.3)	
	Master's + doctoral degree	332.0 (43.6)	
Teaching characteristics	Teaching experience, years: mean (SD)		17.37 (11.09)
	Highest grade taught: n (%)	Elementary school	392.0 (51.5)
		Middle school	103.0 (13.5)
		High school	266.0 (34.9)
School characteristics	School type: n (%)	General	537.0 (70.5)
		Religious	116.0 (15.2)
		Arab	84.0 (44.1)
		Other	24.0 (3.1)
	School district: n (%)	East	119.0 (15.6)
		Center	272.0 (35.7)
		North	305.0 (40.0)
	South	65.0 (8.5)	

3.1.2. Teachers' Remote Teaching Professional Efficacy

Statistically significant differences were observed in the prevalence of teachers with poor-to-average professional efficacy and those with high professional efficacy on all 11 questionnaire items (chi-square range: 68.41 on item 10 to 758.12 on item 3; $p < 0.001$). More specifically, concerning five items, most study participants exhibited high professional efficacy (items 2, 3, 6, 7, and 8), while on six items, most study participants exhibited poor-to-average professional efficacy (items 1, 4, 5, 9, 10, and 11). For a description of the items and additional information, see Table 2.

Table 2. Teachers' remote teaching professional efficacy (N = 761).

Question	Poor–Average Efficacy: n (%)	High Efficacy: n (%)	Chi-Square (p Value)
1. I have the ability to teach PE remotely.	564 (74.11)	197 (25.88)	403.55 (<0.001)
2. The staff at my school emphasizes remote teaching success.	150 (19.71)	611 (80.28)	571.58 (<0.001)
3. It is important that I be able to teach PE remotely.	115 (15.11)	646 (84.88)	758.12 (<0.001)
4. I plan on investing effort in preparing remote PE lessons.	457 (60.05)	304 (39.94)	162.21 (<0.001)
5. The success of my remote teaching depends on me.	538 (70.69)	223 (29.30)	388.35 (<0.001)
6. Most PE teachers I know are successful in remote teaching.	197 (25.88)	564 (74.11)	403.55 (<0.001)
7. Learning PE remotely is valuable.	327 (42.96)	434 (57.03)	205.03 (<0.001)
8. I am confident that I can teach PE remotely.	181 (23.78)	580 (76.21)	480.53 (<0.001)
9. I am expected to succeed in remote teaching.	502 (65.96)	259 (34.03)	347.68 (<0.001)
10. I am planning to learn additional remote teaching techniques.	542 (71.22)	219 (28.77)	68.41 (<0.001)
11. It is easy for me to prepare and deliver remote teaching lessons.	603 (79.23)	158 (20.76)	137.52 (<0.001)

Note: PE, physical education; poor–average efficacy consisted of answers 1 (“strongly disagree”), 2 (“disagree”), and 3 (“average”); high efficacy consists of answers 4 (“agree”) and 5 (“strongly agree”).

3.1.3. Remote Teaching Professional Efficacy: Health Perception Differences

As seen in Figure 1, all study participants reported an overall good health perception. However, in comparison to those with “good health”, participants with “very good health” and “excellent health” had a statistically significantly higher remote teaching professional efficacy (mean scores: 36.60 ± 8.71 , 38.96 ± 6.43 , and 39.74 ± 7.22 , respectively; F-ratio = 7.28, $p = 0.001$). Similarly, statistically significant positive correlations were observed between the remote teaching efficacy score and health perception ($r = 0.22$, $p < 0.001$). Higher remote teaching professional efficacy scores were associated with better general health perceptions.

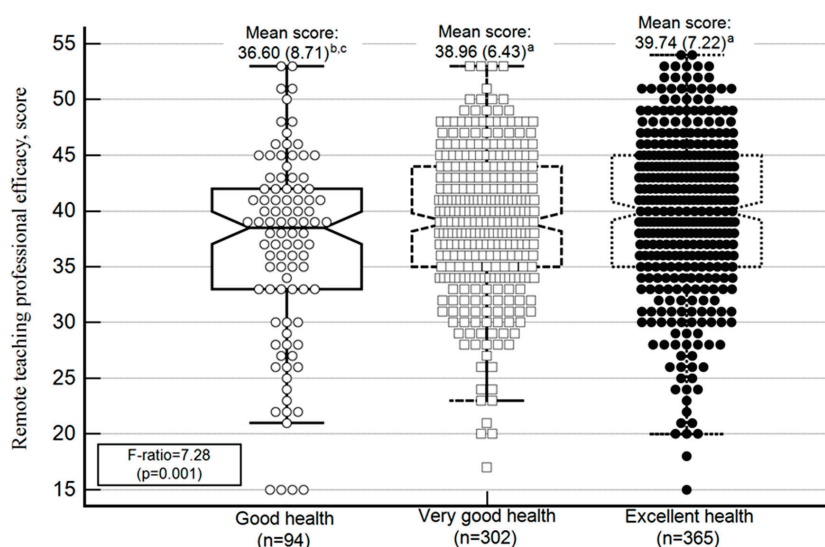


Figure 1. Remote teaching professional efficacy: health perception differences. Note: The central box represents the interquartile range (25th–75th percentiles), with the vertical line covering the full data range. Outliers are shown as separate points, defined as values beyond 1.5 times the interquartile range. The central line represents the median.

3.1.4. Factors Influencing Variations Between Participants with Different Levels of Remote Teaching Professional Efficacy

- Demographic Characteristics

No statistically significant correlations were observed between remote teaching professional efficacy and age ($p > 0.05$). Similarly, no between-group differences in professional efficacy were observed between participants of different religions ($t = 3.45$, $p = 0.06$) and family status ($f = 3.30$, $p = 0.07$). However, compared to males, females were found to have a statistically significantly higher teaching professional efficacy (mean scores: 37.52 ± 7.30 and 40.82 ± 7.00 , $t = 17.92$, $p < 0.001$). Similarly, participants with higher educational levels (master's and doctoral degrees) presented a statistically significantly higher remote teaching professional efficacy than those with lower levels of education (a senior-qualified certificate and bachelor's degree; 40.69 ± 6.69 and 38.54 ± 7.53 , respectively, $t = 4.79$, $p = 0.02$). For additional information, see Table 3.

Table 3. Differences in remote teaching professional efficacy based on categorical socio-demographic, teaching, and school characteristics (N = 761).

Variables			Mean (SD)	t or f Test (<i>p</i> Value)
Demographic characteristics	Family status	Single (n = 88)	38.64 (8.92)	4.67 (0.01)
		In a relationship (n = 613)	38.90 (6.92)	
		Divorced /widowed (n = 60)	41.10 (6.74)	
	Religion	Jewish (n = 647)	39.24 (7.13)	3.45 (0.06)
		Non-Jewish (n = 114)	37.89 (7.41)	
	Education	Senior teacher + bachelor's degree (n = 429)	38.54 (7.53) ^a	4.79 (0.02)
Master's and doctoral degree (n = 332)		40.69 (6.69)		
Teaching characteristics	Highest-grade taught: n (%)	Elementary school (n = 392)	39.51 (7.43) ^b	3.08 (0.04)
		Middle school (n = 103)	39.53 (6.94) ^b	
		High school (n = 266)	37.16 (6.84)	
School characteristics	School type	General (n = 537)	39.39 (7.03) ^c	3.08 (0.04)
		Religious (n = 116)	38.71 (6.96)	
		Arab (n = 84)	35.83 (9.26)	
		Other (n = 24)	38.17 (7.58)	
	School district	East (n = 119)	36.92 (8.48)	4.38 (0.005)
		Center (n = 272)	39.69 (6.52) ^d	
		North (n = 305)	39.31 (7.06) ^d	
		South (n = 65)	38.98 (7.23)	

Note: SD, standard deviation; "a" indicates a statistically significant difference from "Masters and doctoral degree" ($p < 0.05$); "b" indicates a statistically significant difference from "High school" ($p < 0.05$); "c" indicates a statistically significant difference from "Arab" ($p < 0.05$); "d" indicates a statistically significant difference from "East" ($p < 0.05$).

- Teaching and School Characteristics

No statistically significant associations were observed between remote teaching professional efficacy and number of years of teaching ($p > 0.05$). However, as seen in Table 3, teachers in the lower grades (elementary and middle school) presented a statistically significantly greater teaching professional efficacy than those at a higher grade level (high school; $f = 3.08$, $p = 0.04$). Statistically significant differences were also observed between participants teaching in different types of schools. More specifically, participants teaching in the state public Jewish schools showed a statistically significantly greater remote teaching professional efficacy than those teaching in Arab schools ($f = 3.08$, $p = 0.04$). Finally, teachers teaching in the central and the northern part of the country presented a statistically significantly higher remote teaching professional efficacy compared to teachers teaching in the eastern region of the country ($f = 4.38$, $p = 0.005$; Table 3).

- Factors Predicting Remote Teaching Professional Efficacy

Table 4 presents the binary logistic regression results for predicting remote teaching professional efficacy. The regression model explained 17% of the variability in professional efficacy in teaching (chi-squared = 37.44; $p < 0.0001$; Nagelkerke $R^2 = 0.17$). Factors predicting remote teaching professional efficacy were sex, education level, school type, and school district. More specifically, in comparison to male teachers, female teachers exhibited greater professional efficacy in teaching (coefficient = 0.87, odds ratio = 2.38, $p = 0.02$); having master's and doctoral degrees predicted greater professional efficacy vs. having a bachelor's degree or being a certified senior teacher (coefficient = 1.15, odds ratio = 3.17, $p = 0.01$). In comparison to teachers in Arab schools, teachers in the Jewish schools exhibited a higher remote professional efficacy (coefficient = 2.01, odds ratio = 0.13, $p < 0.001$), and finally, teachers in schools in the central and northern part of the country showed greater professional efficacy than teachers in the eastern part of the country (coefficients: 1.70 and 0.99, respectively; odds ratio: 5.48 and 2.69, respectively; $p < 0.001$ and 0.04, respectively).

Table 4. Summary of binary logistic regression analysis to predict remote teaching professional efficacy (N = 761).

Predictors	Coefficient	Standard Error	Wald	Odds Ratio	95% CI	p-Value
Constant	1	0.54	5.74	-	-	0.01
Sex (female vs. male)	0	0.39	4.90	2.38	1.10–5.15	0.02
Education ("Master's + doctoral degree" vs. "Senior teacher and bachelor's degree")		0.47	5.97	3.17	1.25–8.01	0.01
Highest grade taught ("middle school vs. "elementary")		0.58	0.00	1.05	0.33–3.31	0.92
Highest grade taught ("high school" vs. "elementary")		0.44	2.02	1.87	0.78–4.46	0.15
School type ("religious" vs. "general")	0	0.54	0.00	1.00	0.34–2.91	0.98
School type ("Arab" vs. "general")	2	0.58	12.06	0.13	0.04–0.41	<0.001
School type ("other" vs. "general")	0	0.61	0.01	0.93	0.27–3.14	0.91
School district ("center" vs. "east")	1	0.60	7.97	5.48	1.68–17.89	<0.001
School district ("north" vs. "east")	0	0.49	4.01	2.69	1.02–7.12	0.04
School district ("south" vs. "east")	0	0.72	0.50	1.66	0.40–6.85	0.47
Model Summary		Chi-squared = 37.44; $p < 0.0001$; Nagelkerke $R^2 = 0.17$.				

Note: CI, confidence interval; only variables that differed as a function of the dependent variable were entered into the model; remote teaching professional efficacy was dichotomized into those below and above the median score (median score = 39).

In Figure 1, the central box is representative of the values from the lower quartile to the upper quartile. The vertical line extends from the minimum value to the maximum value while excluding the outliers (which are displayed as separate points). An outlier was defined as either (1) a value lower than the lower quartile minus 1.5 times the interquartile

range, or (2) a value higher than the upper quartile plus 1.5 times the interquartile range. The middle line is representative of the median.

- Teaching Professional Efficacy: Gender Differences

An analysis of teaching professional efficacy scores identified a statistically significant difference between males ($n = 258$) and females ($n = 503$). Specifically, females re-reported significantly higher efficacy scores than males (40.82 ± 7.00 vs. 37.52 ± 7.30 , respectively; $t = 17.92$, $p < 0.001$).

- Power Analysis

Post hoc power analysis for the regression model was conducted with 10 predictors, a sample size of 761, and a mean effect size d of -0.05 (range: -0.03 to 0.38). Using these parameters and setting the alpha error probability at 0.05, the power achieved was 0.99. This indicates that this study had a high likelihood of detecting statistically significant effects, if present, given the sample size and the effect sizes observed.

3.2. Qualitative Results

Three main themes emerged from the in-depth analysis of the responses to the six open questions posed to 15 PE teachers: the rapid transition from face-to-face to distance education; professional efficiency in distance education is a critical element for teaching with technology; and successes and challenges in distance education in physical education.

3.2.1. The Rapid Transition from In-Person to Remote Teaching

During the pandemic, circumstances could change daily, raising many questions regarding remote PE lessons. The Ministry of Education sent instructions directly to the school principals who delivered them to the PE staff. Teachers reported that the instructions were often unclear. The swift shift from in-person to distance learning significantly impacted teachers' professional efficacy with respect to remote teaching. The sudden change presented challenges such as adapting to online platforms, integrating technology, and maintaining student engagement. Initially, teachers may have experienced uncertainty and self-doubt. However, with time and support, their professional efficacy in remote teaching developed, especially for those who sought professional development opportunities and embraced a growth mindset.

The pandemic forced us to switch to remote teaching immediately. There were teachers for whom the transition was easy and those for whom it was not. There are teachers in high schools who teach PE who have been trained in digital tools, mainly to teach theoretical material. For them, the transition was relatively easy (PE teacher, 45 years old, male).

In contrast, a 50-year-old female PE teacher said, "Undoubtedly, it was a dreadful experience—akin to a teacher attempting to conduct a class trip over Zoom. It simply doesn't align well. PE, for instance, thrives on social interactions, like engaging in ball games together".

3.2.2. Professional Efficacy in Remote Teaching Is a Crucial Element for Teaching Using Technology

In the interviews, the PE teachers emphasized that advanced knowledge, specialized training, and higher academic degrees contributed to increased confidence and competence in their ability to engage in remote PE teaching successfully. They highlighted their ability to effectively apply theoretical frameworks and research-based strategies to address diverse student needs.

"With my master's degree in PE, I have the tools to create meaningful learning experiences in teaching PE online and I apply research-based strategies to do so, which increases the efficacy of my remote teaching" (PE teacher, 47 years old, female).

Another teacher said, “My doctoral studies gave me a broad understanding of effective PE teaching in both traditional and remote settings. This knowledge empowers me to implement evidence-based strategies, increasing my professional efficacy in remote PE teaching”. (PE teacher, 40 years old, female).

PE teachers also claimed that their professional efficacy was the key factor in dealing with technology. Teachers felt that when they had confidence in their ability to deliver an online lesson, they tended to engage more actively in their teaching, such as setting clear objectives and actively looking for useful resources.

3.2.3. Successes and Challenges in Remote Teaching of PE

The quantitative analysis revealed gender disparities among elementary school teachers. The qualitative data shed light on the professional efficacy of female PE teachers. Female PE teachers expressed their ease in utilizing technology for PE classes, demonstrating creative approaches to distance learning, and feeling confident in delivering online PE lessons during the pandemic, compared to their male counterparts. They described their ability to establish strong relationships with students, creating a supportive and inclusive learning environment for the remote teaching of PE. This is seen in the remarks of one female PE teacher, “I see that my students are engaged during the remote lessons, leading me to believe that they resonate well with them”.

Managing a remote PE lesson has been a challenge for the PE teachers. Some of the teachers joined classes with their camera turned off. According to Ministry of Education policy, students were not required to turn their cameras on, which made it difficult for PE teachers as instructors. This was a source of stress among teachers. The cameras that were off were problematic since it prevented teachers from performing the following: 1. tracking attendance, 2. instructing properly, and 3. providing feedback to students when they performed the exercises and praising them. One male PE coordinator said, “I find that remote PE instruction very difficult and frustrating and therefore, I prefer the traditional way”.

4. Discussion

This study utilized a mixed-methods design to delve into the challenges faced by PE teachers in distance learning. Regarding the first objective, the quantitative analysis revealed a positive association between higher remote teaching professional efficacy and better general health perception among PE teachers. Many teachers successfully transitioned to remote teaching while simultaneously managing their mental and physical well-being, caring for vulnerable family members, and even handling their children’s homeschooling (Kim & Asbury, 2020). Previous research on teachers’ professional efficacy during emergency situations highlighted the significance of eLearning system quality and teacher professional efficacy in their willingness to continue online practices (Centeio et al., 2021; Guoyan et al., 2023). Other studies have also shown that higher professional efficacy among teachers is associated with adopting positive educational practices (San-Martín et al., 2020). Our results show a strong relationship between PE teachers’ efficiency in distance learning and their perceived health, with higher efficiency associated with better well-being. While distance learning brought challenges—such as adapting activities and managing technology—it also opened up opportunities for innovative pedagogy. Teachers who already had experience with digital teaching were better able to adapt, highlighting the need for technology training. In addition, female PE teachers reported having more confidence in distance learning than their male counterparts. Strengthening teachers’ digital competencies, institutional support, and well-being can improve distance learning in physical education and turn challenges into opportunities for improved teaching effectiveness and engagement.

The qualitative data provided additional support and showed how the sudden transition from face-to-face to distance learning impacted the professional effectiveness and performance of distance PE teachers during the pandemic. Several PE teachers had difficult experiences and were unable to deliver PE lessons effectively via Zoom. Most teachers had not received adequate professional training for distance education before the pandemic. Remote teaching raises serious questions about the ability to effectively engage in relationships based on caring, well-being, and connectedness in a context that is unpredictable and unknown (Baker et al., 2022; O'Brien et al., 2020).

Recently, remote teaching has become increasingly prevalent in education systems worldwide (Motamedi, 2001). The shift to remote teaching was not by choice and presented numerous challenges, stress, uncertainty, and complexity. However, what pleasantly surprised us was that during these difficulties, some teachers embraced the situation with a positive outlook (Ferri et al., 2020). They viewed the rapid transition to remote learning as an opportunity to explore new pedagogical approaches, foster unique connections and engagement with learners, challenge prevailing knowledge and perceptions among teachers, and adopt a teaching approach that acknowledged and aligned with the shared social realities of that time. These optimistic perspectives highlight the potential for growth and innovation in remote teaching, encouraging a proactive and positive approach to addressing future challenges (Lambert et al., 2024).

The qualitative data supported the need to provide technical knowledge and practice for PE teachers. PE teachers who had the opportunity to practice remote teaching prior to the pandemic had better experiences and reported higher teacher professional efficacy. PE teacher education should include PE remote teaching so that teachers can have the opportunity to gain knowledge, use digital tools, and embrace the new pedagogy. Technology enables adopting flexible and democratic teaching and learning approaches, granting students increased autonomy and control over their learning process, and fostering the development of cognitive competencies and comprehension (Buckingham, 2013). This refers to the extent to which teachers should feel confident in their ability and capable of effectively engaging and educating students in PE remote learning environments by building relationships in an online space. This is a foundation for cultivating a learning community and committing to a process of self-actualization that requires mutual participation and promotes teachers' and students' well-being (Luguetti et al., 2022). Teachers should prioritize individualized attention to students' needs and interests to enhance online teaching and learning, promote collaboration, and nurture creativity. By adapting teaching methods to the digital environment, educators can create an engaging and inclusive virtual classroom experience (Tari et al., 2022).

Moreover, in light of our findings, it is essential to consider the impact of remote teaching on teachers' health perceptions and well-being and understand the relationship between remote teaching and professional efficacy. Teachers' health perception can provide valuable insight into the factors that contribute to successful remote teaching practices while also ensuring the overall well-being of PE teachers. By examining this relationship, educational institutions may develop strategies and support systems that prioritize both effective teaching and the well-being of PE teachers, ultimately leading to improved educational outcomes, satisfaction, and professional efficacy.

Gender disparities in teaching professional efficacy have been a topic of interest in educational research. Our study explored demographic factors and found differences between the genders (female and male teachers) regarding their attitudes toward remote teaching. Additionally, female PE teachers demonstrated higher remote teaching professional efficacy and more positive attitudes towards remote learning than male PE teachers. These disparities in teaching professional efficacy may be influenced by societal expectations, gender

stereotypes, and differential experiences in the teaching profession (Gray & Leith, 2004; Tiedemann, 2002). Understanding the nature and extent of gender disparities in teaching professional efficacy is crucial for promoting equity and supporting the professional development of all teachers (Bortoleto et al., 2020). While several studies have reported no significant gender differences in teaching efficacy, others have found that female teachers tend to demonstrate higher levels of professional efficacy and confidence in their teaching abilities than their male counterparts (Brandon, 2000; Horvitz et al., 2015).

5. Limitations

There are several limitations to consider regarding the findings of this study. Firstly, this study employed a cross-sectional design with a convenience sample, which may limit the generalizability of the results. Secondly, it is important to conduct further research with larger and more diverse samples, encompassing different geographical locations to obtain a more comprehensive understanding of the relationship between remote teaching efficacy, health, and school characteristics among PE teachers. Thirdly, the use of a relatively small sample size in this study may restrict the generalizability of the findings. Including larger samples in future research endeavors would enhance statistical power and increase the robustness of the conclusions drawn from the data. Addressing these limitations through future research will contribute to a more nuanced understanding of the complex dynamics between remote teaching efficacy, health perception, and school characteristics among PE teachers. By employing more rigorous methodologies and larger and more diverse samples, and by conducting studies in various contexts, we can advance our knowledge and make informed decisions to optimize remote teaching practices in PE lessons.

6. Conclusions

This study examined PE teachers' professional efficiency, health perceptions, and pedagogical approaches of physical education teachers in distance learning. The results show that advanced digital teaching skills and research skills significantly increase the effectiveness of distance education, with female teachers showing more confidence than their male counterparts. While perceived health was not the strongest predictor, the qualitative findings suggest that teachers with positive well-being and previous online teaching experience felt more capable and effective. The findings highlight the need for targeted professional development that focuses on technological pedagogy and research skills and is tailored to teachers' backgrounds. Training programs should equip all physical education teachers with the necessary skills to effectively deliver distance education. In addition, integrating the practice of distance education into physical education's teacher education programs can increase confidence and preparedness for emergency response. While these findings are based on the Israeli context, they also have broader implications for global education systems seeking to improve distance education preparation and support the professional development of physical education teachers.

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Abbreviations

The following abbreviations are used in this manuscript:

EUFAPA European Federation of Adapted Physical Activity
PE Physical Education

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Article

An Exploratory Study of K-12 Teachers' Perceptions of Adopting Open Educational Resources in Teaching

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Abstract: With the increased use of digital resources, the use of open educational resources (OERs) has become more demanding in K-12 education, especially after the outbreak of COVID-19. OERs support teachers by providing them with the ability to adapt or create learning materials to meet students' needs. To engage K-12 teachers in the use of OERs, it is important to understand the factors affecting their willingness to adopt them. This study investigated K-12 teachers' perceptions of using OERs in teaching. The variables, including teachers' perceived ease of use of OERs, perceived usefulness of OERs, and technology integration self-efficacy, were examined. Other factors associated with teachers' intention to adopt OERs were explored. Participants were teachers at a university in the north-eastern United States. Both quantitative and qualitative approaches were applied to analyze the collected data. The results indicated that the proposed variables significantly correlated with intention. Ease of use, usefulness, and technology integration self-efficacy were all significant predictors of teachers' intention to adopt OERs, with perceived usefulness being the strongest predictor. K-12 teachers' perceived advantages and disadvantages of using OERs in teaching are reported and discussed.

Keywords: open educational resources (OER); OER acceptance; self-efficacy; teachers' perceptions; intention to adopt OER

1. Introduction

With the development of information communication technologies (ICT) and the pervasive use of the Internet, teachers have the opportunity to access a wide variety of digital or web-based resources (Baas et al., 2022). Most online resources are restricted for use under copyright. Open educational resources (OERs) that allow the re-use of materials or resources have gradually gained educators' attention in K-12 and higher education settings (Baas et al., 2022; Chiorescu, 2017; Clinton-Lisell, 2022; Clinton-Lisell & Kelly, 2024; Hilton, 2020; Y. T. Kuo et al., 2025; Tang, 2021). The term Open Educational Resources (OERs) was first introduced by UNESCO in 2002 through a forum on Open Courseware (OCW) with the intention of describing the free distribution of university educational materials in the virtual learning environment (Butcher et al., 2015). According to UNESCO (2019), OERs are "learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others" (UNESCO, 2019, definition and scope section).

OERs provide users with permission to retain, reuse, revise, remix, and redistribute resources, known as the 5R characteristics of OERs (Wiley & Hilton, 2018; Wiley, n.d.). The “retain” feature allows users to download and keep their own copy of resources (Hilton, 2016). “Reuse” gives users the permission to use the original, revised, or remixed OERs (Wiley & Hilton, 2018). “Revise” refers to the right to edit, adapt, or modify users’ own copies of resources, and “remix” give users the opportunity to create new resources by combining original or revised resources with other existing materials (Wiley, n.d.). “Redistribute” refers to the right to share or disseminate resources that are in the original, revised, or remixed form, without restrictions (Hilton, 2020).

Educational OER materials include, but are not limited to, courses, textbooks, videos, test items, and podcasts (Clinton-Lisell, 2021; Hilton et al., 2019; Wiley & Hilton, 2018). They are often licensed through Creative Commons that provide permission for reuse and revision to fulfill the needs of educators and students (Hilton et al., 2019). With the nature of free availability, OERs can benefit students in several ways (Hilton, 2016, 2020). For example, the use of OERs can reduce students’ expenses of purchasing commercial textbooks and provide students with the opportunity of equal access to learning materials that may not be affordable for some students due to the issue of high costs for traditional textbooks (Fischer et al., 2021; Hilton, 2020). In addition to the benefits of cost savings and equal availability of learning resources, the remixable feature of OERs has the potential to allow teachers to create customized or personalized materials that can better engage students in the learning process (Clinton-Lisell, 2021; The William and Flora Hewlett Foundation, n.d.).

The implementation of OERs in K-12 schools is on the rise. Especially after the outbreak of COVID-19, free and accessible online or digital materials have been in high demand from both teachers and students (Tang, 2021). OERs provide teachers with opportunities to retain, reuse, revise, remix, and redistribute educational materials at no additional financial cost (Read et al., 2020). The flexibility of OERs allows K-12 teachers to freely access high-quality resources and develop materials that are customized to their students’ needs and learning preferences (Avila et al., 2020; Hilton, 2016; Tang, 2021). The use of OERs with proven efficacy and trusted quality has been envisioned as an effective way for K-12 schools to achieve the outcome of delivering high quality learning at a low cost (de los Arcos et al., 2016; Avila et al., 2020; Hilton, 2020; The William and Flora Hewlett Foundation, n.d.).

The adoption and use of OERs has become important in K-12 education (Tang, 2020). With many initiatives having been launched by the United States Department of Education to promote the use and implementation of OERs in K-12 curriculum (Hilton, 2020), it is essential to explore the factors that may have an influence on teachers’ use or adoption of them and to understand K-12 teachers’ perceptions of using OERs in their teaching. Limited studies have investigated K-12 teachers’ perceptions or adoption of OERs, with most of those studies attributing the adoption of OERs to the factor of cost savings (Blomgren, 2018; Y. C. Kuo et al., 2024; Tang et al., 2020). It is therefore critical to explore other factors associated with teachers’ adoption of OERs (de los Arcos et al., 2016; Tang, 2020; Tang et al., 2020). This study investigated K-12 teachers’ perceptions of adopting OERs in teaching, with a focus on factors including perceived ease of use, perceived usefulness, technology integration self-efficacy, and intention of OER adoption.

2. Literature Review

2.1. Open Educational Resources (OER) in K-12 Education

Foreseeing the potential of OERs in K-12 education, the United States Department of Education launched a campaign #GoOpen to encourage K-12 school districts and teachers to participate in the OER implementation plan (U.S. Department of Education, 2015). With

the goal of this campaign being to ensure access of all students to high-quality learning resources, school districts and teachers were encouraged to adopt freely accessible, openly licensed educational materials rather than using traditional textbooks (U.S. Department of Education, 2015). Through the #GoOpen campaign, a network of multiple school districts across the nation was established to actively advocate for the adoption and use of OERs in K-12 curriculum and to share strategies and receive support. In addition, a launch pack was designed to guide school districts in the implementation process of incorporating openly licensed educational resources into the curricula. The implementation process included five phases, i.e., recommending tasks for districts to develop goals and a strategic plan, determine a team of key personnel (e.g., stakeholders and teacher leaders), identify the infrastructure needed for learning, ensure the quality of resources, and design professional learning (Office of Educational Technology, n.d.).

OERs are shared in different forms (e.g., open ebooks, open lesson plans, open textbooks, etc.) and through a variety of multimedia platforms (e.g., Blogs, Wikis, etc.) (Kimmons, 2015). A few examples of OER platforms or repositories that share resources for K-12 educators and teachers include OER Commons (<http://oercommons.org>, accessed on 15 December 2024), the Digital Public Library of America (<http://dp.la>, accessed on 15 December 2024), OpenStax (<https://openstax.org/> (accessed on 15 December 2024)), and CK-12 (<https://www.ck12.org/> (accessed on 15 December 2024)). Among these platforms, OpenStax and CK-12 provide open textbooks that are free for teachers and students to download and share in original or adapted formats. Additionally, teachers are given the opportunity to create and curate the content of textbooks based on their teaching needs.

The Digital Public Library of America provides digital materials which are in the public domain or comprise openly licensed content, from libraries, archives, museums, and other cultural institutions in the United States.

2.2. *Intention to Adopt OERs and Other Relevant Variables*

2.2.1. *Intention, Ease of Use, and Perceived Usefulness*

The technology acceptance model (TAM) developed by Davis (1989) describes how users come to accept and use technology and information systems. In TAM, perceived ease of use (PEU) and perceived usefulness (PU) are two important factors in determining users' intention to accept or use technology (Davis, 1989). Perceived ease of use refers to the degree of effort which users believe is required of them to use a given technology (Davis, 1989). Perceived usefulness indicates the degree to which users perceive the use of a particular technology tool in terms of enhancing their job performance (Davis, 1989). This model has been applied to a wide range of studies in various fields (Bessadok, 2022; Huang et al., 2020; Y. C. Kuo et al., 2024). In teacher-related studies in K-12 education, TAM serves as a critical framework that addresses how teachers intend to integrate technology into their classrooms (Granic & Marangunic, 2019; Y. C. Kuo et al., 2023; Teo, 2009). Relevant research has extended the original TAM by including additional predicting variables for teachers' technology acceptance beyond the aforementioned two variables (Granic & Marangunic, 2019; Khlaisang et al., 2021; Teo, 2019).

In the context of OER use, TAM is a prominent model that helps explain users' intention to adopt OERs for various purposes (Kim et al., 2015). However, there is limited research on the application of TAM for OER use (Kelly, 2014; Kim et al., 2015; Pappas et al., 2017). Notably, studies involving pre- or in-service teachers' acceptance of OERs are scarce (Tang et al., 2020, 2021). For example, according to a study by Kim et al. (2015) that investigated students from the Korea National Open University, perceived ease of use was found to have an effect on intention to use OERs, but perceived usefulness was not a significant predictor for intention. Kelly (2014) focused on educators from K-12, higher education, and

workplace training settings and found that usefulness had a greater effect on educators' intention to use OERs compared to perceived ease of use. In terms of studies related to teaching in K-12 environments, Tang et al. (2020) evaluated 68 K-12 teachers' intention to adopt OERs and found that both perceived ease of use and usefulness significantly predicted intention. Another study of Tang et al. (2021) found that K-12 teachers' perceived ease of use toward OERs increased after participating in open educational practices.

2.2.2. Technology-Integration Self-Efficacy

Self-efficacy refers to the degree to which an individual is confident to take charge of particular tasks, assignments, and challenges (Bandura, 1977). The concept of self-efficacy has been applied to a wide range of studies in various fields and learning environments, such as classrooms, hybrid, or online learning settings (Y. C. Kuo et al., 2014, 2020, 2025). Research on education has indicated self-efficacy as a critical factor in determining students' learning outcomes (Girasoli & Hannafin, 2008; Y. C. Kuo et al., 2020; Y. T. Kuo & Kuo, 2023; Tsai et al., 2011). In the research involving pre- and in-service teachers, self-efficacy was associated with teachers' perceptions of their ability to provide meaningful instructional experiences, as well as their willingness to implement new and innovative pedagogical strategies or technology tools (Moore-Hayes, 2011).

Self-efficacy for technology integration is a significant factor in assuring teachers' perceptions of preparedness for successful technology adoption and implementation in teaching (Y. C. Kuo et al., 2023; Lestari & Indrasari, 2019; Moore-Hayes, 2011). It refers to the degree to which teachers are confident in their ability to successfully incorporate technology into teaching to enhance students' learning experiences (Hur et al., 2015; Y. C. Kuo et al., 2023). Teachers who have higher levels of technology integration self-efficacy are more likely to adopt appropriate tools in instructional planning and preparation processes and to use them in an effective way to promote meaningful learning (Jones et al., 2017; Kent & Giles, 2017). Therefore, in this study, we presume that technology integration self-efficacy is critical to teachers' intention regarding OER adoption in teaching.

3. Research Questions

1. What are teachers' perceived ease of use of OERs, perceived usefulness of OERs, technology integration self-efficacy, and intention to adopt OERs?
2. What are the relationships between teachers' perceived ease of use of OERs, perceived usefulness of OERs, technology integration self-efficacy, and intention to adopt OERs?
3. Do teachers' perceived ease of use of OERs, perceived usefulness of OERs, and technology integration self-efficacy predict intention to adopt OERs?
4. What are teachers' perceived advantages and disadvantages of using OERs in teaching?

4. Method

4.1. Participants

The participants in this study comprised 27 teachers enrolled in an online learning course (see Table 1). The graduate-level course was offered online by the College of Education at a north-eastern university in the United States. The majority of these teachers were aged between 20–30 (63%) or 31–40 years (18.5%). The majority of the participants were female teachers (77.8%) and a few were male teachers (22.2%). About 52% of these teachers had been teaching for 1–5 years, and 25.9% for 6–10 years. A few teachers (22.2%) had teaching experience of 10 years or more. In terms of their self-rated technology skills, about 51.9% described themselves as possessing substantial technology skills. About 29.6% of teachers indicated themselves as being technology experts. About 18.5% of them had moderate technology skills.

Table 1. Background Information.

Characteristic	<i>n</i>	%
Gender		
Male	6	22.2
Female	21	77.8
Age		
20–30	17	63.0
31–40	5	18.5
40–50	3	11.1
51 and above	2	7.4
Years of teaching experiences		
1–5	14	51.9
6–10	7	25.9
10 and above	6	22.2
Technology skills (self-rated)		
Moderate	5	18.5
Substantial	14	51.9
Expert	8	29.6

4.2. Data Collection

An online survey was used to collect the data. The study was approved by the university's Institutional Review Board (IRB), and informed consent forms were obtained from the teachers who participated in the survey. An online survey was provided to teachers at the end of the semester. The survey questionnaire included several sections, such as background information, perceived ease of use of OERs, perceived usefulness of OERs, technology integration self-efficacy, intention to adopt OERs (see Table 2), and reflection on this topic. Background information included gender, age, years of teaching experiences, and technology skills.

Table 2. Instruments.

Scales	Number of Items	Range	Cronbach's Alpha
Perceived ease of use of OERs	3	1–7	0.95
Perceived usefulness of OERs	3	1–7	0.98
Technology integration self-efficacy	6	1–6	0.82
Intention to adopt OERs	2	1–7	0.94

The three scales, measuring teachers' technology acceptance, contained perceived ease of use of OERs, perceived usefulness of OERs, and intention to adopt OERs. The scales were adapted from those developed by Teo (2009). Both scales for measuring teachers' perceived ease of use of OERs and usefulness of OERs had three items. The intention to adopt OERs scale had two items. All three scales were a 7-point Likert scale. The technology integration self-efficacy scale, developed by Moore-Hayes (2011), was adopted in this study. As a 6-point Likert scale, it had six items to measure the confidence level that the teachers possessed in terms of integrating technology into teaching. Table 2 provides an overview of each scale.

4.3. Context

Teachers were asked to participate in an assignment that provided them with opportunities to review materials and online resources, including the introduction of OERs, applications of OERs, as well as some OER examples and websites or platforms that offer OER materials for K-12 educators. Teachers were required to explore existing OER lessons, OER resources, and OER teaching materials that were created by others and share their opinions with their classmates about how they felt these OER resources or materials could be beneficial to their teaching through online discussion boards.

4.4. Data Analysis

Data were analyzed using quantitative and qualitative approaches. Quantitative approaches included descriptive, correlation, and regression analyses. SPSS 26 was used for data analyses. A content analysis was performed for the qualitative approach.

5. Results

5.1. RQ1: What Are Teachers' Perceived Ease of Use of OERs, Perceived Usefulness of OERs, Technology Integration Self-Efficacy, and Intention to Adopt OERs?

Table 3 shows teachers' average scores for four variables. The average score of teachers' perceived ease of use of OERs was 6.30, which is above the midpoint 4. The average score of teachers' perceived usefulness of OERs was 6.15. Teachers had a moderate/average score for technology integration self-efficacy ($M = 4.41$, $SD = 0.42$). Teachers appeared to show the willingness to adopt OERs, with a slightly high mean for intention to adopt OERs ($M = 5.30$, $SD = 0.81$).

Table 3. Descriptive Information.

Scales	Range	Midpoint	<i>M</i>	<i>SD</i>
Perceived ease of use of OERs	1–7	4	6.30	0.98
Perceived usefulness of OERs	1–7	4	6.15	0.67
Technology integration self-efficacy	1–6	3.5	4.41	0.42
Intention to adopt OERs	1–7	4	5.30	0.81

5.2. RQ2: What Are the Relationships Between Teachers' Perceived Ease of Use of OERs, Perceived Usefulness of OERs, Technology Integration Self-Efficacy, and Intention to Adopt OERs?

Table 4 indicates the correlations between perceived ease of use of OERs, perceived usefulness of OERs, technology integration self-efficacy, and intention to adopt OERs. Intention to adopt OERs was positively related to perceived ease of use of OERs ($r = 0.64$, $p < 0.01$), perceived usefulness of OERs ($r = 0.79$, $p < 0.01$), and technology integration self-efficacy ($r = 0.60$, $p < 0.01$). Technology integration self-efficacy had a positive relationship with perceived ease of use of OERs ($r = 0.19$, $p > 0.05$) and perceived usefulness of OERs ($r = 0.52$, $p < 0.01$). Perceived ease of use of OERs was positively correlated with perceived usefulness of OERs ($r = 0.46$, $p < 0.05$).

Table 4. Correlations among Variables.

	Perceived Ease of Use of OERs	Perceived Usefulness of OERs	Technology Integration Self-Efficacy	Intention to Adopt OERs
Perceived ease of use of OER	–	0.46 *	0.19	0.64 **
Perceived usefulness of OER		–	0.52 **	0.79 **
Technology integration self-efficacy			–	0.60 **
Intention to adopt OER				–

Note. * $p < 0.05$; ** $p < 0.01$.

5.3. RQ3: Do Teachers' Perceived Ease of Use of OERs, Perceived Usefulness of OERs, and Technology Integration Self-Efficacy Predict Intention to Adopt OERs?

The multiple regression model (see Table 5) was significant: $F(3, 23) = 42.79, p < 0.001$. The model explained 75% of the variance in intention to adopt OERs. Perceived ease of use of OERs ($\beta = 0.329, p < 0.01$), perceived usefulness of OERs ($\beta = 0.580, p < 0.001$), and technology integration self-efficacy ($\beta = 0.239, p < 0.05$) significantly influenced intention to adopt OERs. Among the three variables, perceived usefulness of OERs was the strongest predictor of perceived learning.

Table 5. Multiple Regression Model: Perceived Learning Explained by Three Predictor Variables.

Variables	B	SE B	β	t	p
Perceived ease of use of OERs	0.272	0.076	0.329	3.92	0.002 **
Perceived usefulness of OERs	0.701	0.127	0.580	2.77	0.000 ***
Technology integration self-efficacy	0.467	0.186	0.239	2.09	0.019 *

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5.4. RQ4: What Are Teachers' Perceived Advantages and Disadvantages of Using OERs in Teaching?

Table 6 provides an overview of teachers' perceived advantages and disadvantages of using OERs in teaching. Two major themes were making instructors' class preparation more efficient (i.e., saving time creating materials) and enhancing students' learning experience (i.e., increasing student engagement). The four advantages mentioned by teachers most frequently were cost savings, differentiation, easy accessibility of OERs, and the possibilities of the modification and reuse of OERs. Teachers felt that the use of OERs would help reduce the cost of purchased textbooks or materials and enhance differentiation in their instruction to meet students' needs or interests. Being able to freely access, reuse, and curate OER resources is beneficial to teaching preparations. For example, one teacher indicated that "you can start with materials that others have provided but make them your own by adding unique touches". Some teachers indicated the use of OERs would enhance educational equality and allow students in the low-income areas to have the opportunity to access high-quality online lessons or resources. OERs allow teachers to share their work and collaborate with other teachers. The use of OERs would also benefit students by increasing their learning engagement and 21st century skills such as collaboration and innovation.

Three major negative themes were instructors' lack of experience with OERs (lack of training), concerns regarding the OER content (e.g., the authenticity of the content), and issues related to the use of OERs for students and parents (e.g., fewer student–teacher interactions). The three disadvantages indicated most frequently by teachers were the lack of alignment of OERs to state or academic standards, a lack of knowledge about reusing, adapting, or attributing OERs, and a lack of time to search for OERs. Teachers also indicated difficulties in terms of finding OERs for specific subject areas and determining which resources to use. For example, one teacher mentioned that "it can become very overwhelming to search, locate, and evaluate resources before putting them into practice". Some teachers were concerned about the quality of OERs, as they may be created by non-teachers, and some OERs might be outdated or need content validation. Technical difficulties were another concern, as teachers or students might not be able to download or use OERs, and some OERs might have glitches. Several teachers felt that the use of OERs might lead to a decrease in students' social skills and fewer interactions among students, parents, and the teacher. OERs appeared to be more suitable for older students. In addition, teachers mentioned that some school districts might not allow the use of OERs, and the

lack of training regarding OERs may discourage teachers from using them. For example, one teacher noted that “we have to follow strict curriculum for certain subjects”.

Table 6. Summary of Advantages and Disadvantages.

Advantages	• Cost savings (11) • Differentiation/meet the needs of students (10) • Allow for modification and reuse (8) • Easy access (8) • Increase student engagement (5) • Increase educational equality (4) • High-quality lessons (4) • Save time for creating materials (4) • Foster collaboration between educators (3) • Increase students’ 21st century skills (2)
Disadvantages	• Lack of alignment of OERs with academic or state standards (9) • Lack of knowledge of reuse/adaptation/attribution rules of OERs (7) • Time consuming to search for OER (7) • Difficulty in finding or knowing where to search for OERs (6) • The quality and consistency of OERs may vary (4) • Technical difficulties in downloading or using OERs (4) • Learning issues for students, such as a decrease in students’ social skills, fewer student/teacher interactions, low ease of use for younger students (4) • The authenticity of the content may be lacking (3) • Constraints from school districts (2) • Lack of training regarding the use of OERs (1) • Disconnect with parents (1)

Note: The numbers in the parentheses refer to the frequency of terms or phrases indicated by teachers.

6. Discussion

Based on the results of our analysis, overall, teachers in this study were found to be positive about the use of OERs in teaching. Our descriptive analysis shows that most teachers perceived OERs as being easy to use, found OERs to be useful in enhancing teaching effectiveness or productivity, and intended to adopt OERs in their future teaching. On average, these teachers held a moderately high level of self-efficacy in terms of incorporating technology into the classroom.

Based on the correlation analysis, teachers’ perceived ease of use, perceived usefulness, and their intention to adopt OERs were found to be positively correlated with each other at a significant level. This implies that the higher the perceived ease of use and usefulness of OERs, the more likely that teachers were to be willing to use OERs in their teaching. This finding corresponds to the study of Tang et al. (2020), in which the correlations between three variables of OER acceptance were found to be significantly positive among school teachers. Also, other TAM studies have found positive relationships between intention to use, perceived ease of use, and perceived usefulness (Granic & Marangunic, 2019; Khlaisang et al., 2021; Teo, 2019). In terms of technology integration self-efficacy, it was found to be significantly related to perceived usefulness of OERs in a positive way, indicating that teachers with higher levels of self-efficacy in integrating technology into teaching are more likely to perceive OERs as useful educational resources. However, teachers’ technology integration self-efficacy was not found to be significantly correlated with perceived ease of use. This may have been due to the fact that most OERs are easy to use, not requiring lots of effort on the part of teachers; therefore, the average scores of ease of use did not show significant differences in technology integration self-efficacy.

In terms of the regression analysis, teachers’ perceived ease of use of OERs, perceived usefulness of OERs, and technology integration self-efficacy all significantly predicted

their intention to adopt OERs. Among the three predictors, perceived usefulness of OERs was the strongest predictor, followed by perceived ease of use of OERs and technology integration self-efficacy. This finding is consistent with the results from previous studies that applied TAM to investigate teachers' acceptance of various technological tools and found that both perceived ease of use and perceived usefulness were significant predictors of teachers' intention for technology adoption (Granic & Marangunic, 2019; Tang et al., 2020). Furthermore, these prior studies also indicated that perceived usefulness had a stronger effect on intention for adoption compared to perceived ease of use (Granic & Marangunic, 2019; Tang et al., 2020). The significant influence of technology integration self-efficacy on intention for OER adoption, which was not investigated in prior OER studies for teachers, implies that teachers' confidence in integrating technology is a determinant of their intention to adopt OERs in teaching. This finding contradicts the study conducted by Kim et al. (2015), in which adults' self-efficacy in terms of using OERs did not have a significant effect on their intention to use OERs. The participants in our study were K-12 teachers in the United States, while the participants in the study of Kim et al. (2015) were adult students enrolled in an open university in South Korea; the sample in the latter study might have included both educators and non-educators, and the details of participants were not mentioned.

The findings of the present study about teachers' perceived advantages (e.g., cost savings, differentiation, accessibility, reuse/modification features, etc.) of using OERs are aligned with the results from previous OER studies (Hilton, 2020; Kwak, 2017; Tang, 2020), where OERs were found to have the potential to improve teachers' preparations of teaching materials or resources. Tang (2020) indicated that teachers perceived OERs as resources that are easily accessible with no cost, saving teachers' time regarding the creation of high-quality materials, and helping with personalized instruction. The advantage of fostering collaborations among teachers when using OERs, as found in this study, corresponds to the research of Tang (2020), in which the use of OERs was found to promote the development of reciprocal exchanges among educators. Our study found that the use of OERs contributes to student learning experiences, resulting in an increase in student engagement and the development of students' 21st century skills. Consistent with the study conducted by Nkwenti and Abeywardena (2019) that involved a group of pedagogic supervisors, OERs were found to have the potential to increase learners' engagement with the lesson content. The advantage of enhancing students' 21st century skills, as a new finding, was not indicated in prior OER studies. The features of OERs enable users to collaboratively reuse and modify the content (Wiley & Hilton, 2018; Clinton-Lisell, 2022). Teachers may see the opportunity for their students to recreate new learning content using OERs in course activities, which helps to improve students' 21st century skills. In terms of teachers' perceived disadvantages of using OERs, most teachers had the concern about the misalignment of OERs with curriculum or state standards. Corresponding to the study of de los Arcos et al. (2016), school teachers around the world indicated that OERs that are not aligned with professional standards as one of the challenges. Other disadvantages (e.g., a lack of knowledge of attribution rules for OERs, not having enough time to find OERs, technology problems, etc.) found in our study were aligned with those indicated by some prior studies (de los Arcos et al., 2016; Nkwenti & Abeywardena, 2019; Ozdemir & Bonk, 2017; Tang, 2020). Two disadvantages, including learning issues for students (i.e., decreasing students' social skills, fewer student/teacher interactions, age appropriateness, etc.) and the disconnection with parents, were not found in previous research. Interestingly, some advantages contradicted stated disadvantages. For example, some teachers thought that OERs provide high-quality lessons; however, some teachers had concerns about the quality and consistency regarding the OER content.

7. Conclusions and Implications

Overall, in this study, teachers appeared to be positive about the adoption of OERs in teaching. Positive relationships were found among perceived ease of use, perceived usefulness, technology integration self-efficacy, and intention for OER adoption. Teachers' perceived ease of use, perceived usefulness, and technology integration self-efficacy were all significant predictors of their intention to adopt OERs, with perceived usefulness being the strongest predictor. This study adds to our understanding of the factors that have an influence on teachers' adoption of OERs. Based on TAM, the critical roles of teachers' perceived ease of use and perceived usefulness in intention for OER adoption were verified in our study. Beyond that, we examined and identified the importance of teachers' technology integration self-efficacy in OER adoption or use, which was not explored in prior OER research related to teachers. In addition, the qualitative results summarized the advantages and disadvantages that teachers perceived about using OERs in teaching.

In terms of practical implications, this study suggests that school leaders, administrators, and policymakers should pay attention to the benefits of OERs in terms of enhancing teaching and provide teachers with assistance, incentives, and support to encourage them to adopt OERs in their class. Providing teachers with professional development or training on OERs would help increase their motivation and willingness to use or adopt OERs. Through professional development, the features of OERs (e.g., reuse, accessibility, etc.) and the benefits of using them should be presented with available OER resources and platforms, examples of OER-integrated lessons or curriculum, and hands-on practice, which would help increase teachers' perceived ease of use and usefulness regarding OERs. School districts and teacher educators should provide teachers with low levels of technology integration self-efficacy with additional support or training opportunities to reinforce their acceptance of using OERs. Pairing these teachers with teachers with high levels of technology integration self-efficacy would allow those with low confidence in technology integration to see successful examples of OER integration and receive mentoring from their colleagues when encountering problems when using OER resources. School leaders are advised to provide Q&A sessions or organize informal gatherings for teachers to report problems or issues and discuss ways to overcome them.

There are some limitations in our study. First, the results were drawn from a group of teachers from a single institution in the United States, and such results may not be generalizable to teachers from other countries with different cultures and educational requirements. Second, the sample size of this study was small; future studies should include a larger sample size of teachers to verify the significant effect of the proposed predictor variables on teachers' intention to adopt OERs. Third, our study focused on exploring the influence of three variables (i.e., perceived ease of use, perceived usefulness, and technology integration self-efficacy) on teachers' intention to use OERs. Other variables, which were not included in this study, may have a potential influence on teachers' intention to adopt OERs in teaching. Researchers are encouraged to expand the exploration of variables associated with teachers' intention for OER adoption based on TAM.

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Article

Teachers Can Use It with Their Littles: Using Case Studies to Explore Preservice Teachers' Perceptions of Technology

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Abstract: This study explores preservice teachers' (PSTs') attitudes toward technology through case studies conducted in a technology-focused course. Nine PSTs completed four case studies addressing screen time guidelines, virtual reality, the digital divide, and ChatGPT-4. Using the SAMR (Substitution, Augmentation, Modification, Redefinition) model as a coding framework, researchers analyzed 36 written reflections. PSTs often viewed technology as a substitute rather than a transformative tool. While many PSTs expressed skepticism about technology, others acknowledged the potential of tools like ChatGPT to enhance teaching, e.g., providing real-time feedback on writing and translating assignments into native languages. The study underscores the value of case studies in helping PSTs critically evaluate technology's role in teaching and learning. Despite recognizing its inevitability, PSTs need further support to embrace transformative technology use.

Keywords: preservice teachers; case studies; technology integration

1. Introduction

Technology has often been used to help teachers adapt lessons to meet students' needs (Bernacki et al., 2020). Nevertheless, using technology requires teachers to be familiar with the technology and how to use it to effectively improve instruction (Wilson, 2023). It also requires that teachers are aware of students' comfort or ability to use technology and whether that technology use will improve upon children's understanding (Dong & Mertala, 2021). While teachers may have had exposure to technology through their teacher preparation programs, the dynamic, rapid pace of technology can quickly make education outdated and cause trepidation among preservice teachers (PSTs). PSTs' who feel comfortable using technology are more likely to use it in their classroom (Jita & Sintema, 2022), thus it is important to consider PSTs' feelings toward teaching with technology.

Puentedura's (2014) model of technology integration is a framework for how to gradually integrate technology. The SAMR (Substitute, Augment, Modify, Redefine) model has been used in studies exploring in-service and PSTs' technology integration by documenting how technology use can enhance and transform learning (Vogt & Westerlin, 2021). Gradual integration of technology, starting with direct substitution, may be more practical for PSTs than full-scale implementation (Schriever, 2021). Nevertheless, there is limited research focusing on how PSTs can differentiate SAMR levels or use SAMR as a conceptual framework (Zipke et al., 2019).

This study examines PSTs' feelings toward technology and the level of technology integration as seen in their analysis of case studies. As a teaching method, case studies have been used in prior research to provide PSTs with integrated learning opportunities (Torres

et al., 2023). Case studies provide hands-on opportunities to explore teaching scenarios before they enter the classroom, enabling students to think about the broader implications of technology without constraints (Toogood, 2023). They present real-world situations that model the ethical or moral dilemmas PSTs may face related to technology integration, illuminating PSTs' underlying emotions or beliefs more authentically than a survey or questionnaire. While previous research has explored PSTs' use of technology through case studies involving problem-solving (Qian et al., 2023), instructional design skills (Koehler et al., 2019), or technological content knowledge (Saltan, 2017), there has not been recent research exploring PSTs' feelings toward technology and technology integration as evidenced in their responses to case studies. This study was concerned with how PSTs described technology integration across four case studies, where each one offered an additional opportunity to reexamine their feelings toward technology. The research questions that guided this study are (a) in what ways do PSTs describe integrating technology (according to the SAMR model) given specific case studies, (b) whether PSTs described technology positively or negatively, and (c) what differences emerged, if any, in how PSTs described technology across the various case studies.

2. Conceptual Framework: The SAMR Model

The SAMR model approaches each use or application of technology as a different task and provides teachers with scaffolding to leverage more technology more purposefully (see Table 1).

Table 1. Description and Example of SAMR Levels.

	SAMR Description	Examples
Enhancement	Substitution—technology acts as a direct substitute with no functional improvement. Often, the technology use saves paper and/or time.	Having students type answers instead of handwriting them. Using an online document instead of a paper/pen quiz.
	Augmentation—technology acts as a direct substitute, with functional improvement; technology provides some access to information.	Teacher instruction is supplemented with a video that clarifies directions. Students are able to use the internet to search for information about a topic.
Transformation	Modification—technology allows for significant task redesign from traditional assignments into more interactive tasks that allow for more student collaboration; tasks often move beyond “paper” tasks.	Students create a video presentation using their voice and other digital elements instead of an oral presentation. Students create digital book reports that utilize animation and graphics.
	Redefinition—technology allows for the creation of new tasks previously inconceivable; learning is often connected with real-world applications.	Using Google Earth to measure distance or landforms. Accessing real-time data and using software to create data visualizations. Participating in virtual dissections using VR headsets.

On the first level, substitution, the teacher exchanges a selected activity with a piece of technology, for example, offering a digital form of a worksheet. Technology offers some advantages, but the form of learning is the same. In augmentation, the teacher uses technology to improve the task process in a way that could not be accomplished with a paper/pencil task. Rather than simply filling in answers to a problem on a digital worksheet, students might write answers in a word processing program. This software allows students the ability to insert images or change the way that text looks, thereby enriching the learning

process. These first two levels are often called enhancement because the format of the activities is unaltered. On the modification level, the teacher fundamentally changes and improves upon the task using technology, opening doors that were previously closed. In the above example, the teacher may post the Word document in a shared online document, allowing students to collaborate, comment, and simultaneously view the document. Offering an online version enables students to provide immediate feedback, simultaneously engage in the writing process, and create hyperlinks to websites, videos, or other media. Finally, redefinition occurs when the original task is redefined by the way technology is integrated. The original task is now impossible without the use of technology (Hilton, 2016b). The final two levels of the SAMR model are often called transformative because of how learning and assignments are changed by technology use.

Studies of teachers' SAMR use have consistently found that teachers tend to use lower levels of technology integration in their classrooms (Hughes et al., 2015). Martin (2020) found that most PSTs' responses fell within the substitution tier or at the beginning of the augmentation. Setyaningish (2020), exploring English teachers' technology use, similarly found that most activities commonly fell into substitution and augmentation. However, the level of technology integration may depend upon the purpose of a particular lesson and not the comfort of the technology integration itself. Hilton (2016a) found that participants were more likely to use lower levels for content acquisition, while modification and redefinition were used to practice skills later in a lesson or unit. It may also depend upon the content. For example, Hilbrand's research on social studies teachers found that it was more common for technology use to fall into the substitution and augmentation levels of SAMR, while activities that included social studies skills practice often fell into modification and redefinition. While previous studies explored how teachers use the SAMR model to integrate technology, the model can also present a useful analytical tool to explore to what extent PSTs envision integrating technology.

3. Literature Review

An abundance of research has examined PSTs' beliefs about technology use. Cherner et al. (2014) suggest that these beliefs can be comprised of two categories: resources and instruction. PSTs use technology to accomplish tasks, i.e., using software to take attendance; generally, PSTs are favorable of this use. The second use is an instructional tool, of which the views are quite mixed. On the one hand, PSTs believe that the primary benefit of technology is in children's increased motivation and engagement (Brown et al., 2016). However, PSTs have low self-efficacy in implementing technology into their teaching. Integrating technology into lessons requires additional planning and preparation that many PSTs do not have (Polly et al., 2010).

Research specifically with early childhood PSTs' views of technology indicates that beliefs are dependent upon the child's age when using the technology. For example, technology is a friend to older children but a foe to young children (Dong & Newman, 2016). Similarly, technology is viewed positively as a way to enhance learning but viewed negatively when thinking about children's social development. Teachers may believe that children are on devices a significant portion of the time at home; thus, their classrooms should be technology-free out of concern for children's physical and mental health (Mertala & Salomaa, 2016).

Much of the other literature on PSTs' views of technology can be explored through the context of specific kinds of technological use, i.e., artificial intelligence or virtual reality. Limited research has explored how PSTs feel about these kinds of technology and how they may use it in their field placements or classrooms. The remaining literature review will look at these examples to provide context for the case studies used in this study.

3.1. Screen Time

Screen time refers to the amount of time spent in front of a screen, whether that be a television, tablet, computer, or smartphone (Beatty & Egan, 2020). The American Academy of Pediatrics (2016) recommends that children between the ages of two and five be limited to no more than one hour of screen time per day, with an emphasis on educational content. For older children, consistent limits should be established to ensure that screen time is balanced with sleep, physical activity, and other health behaviors. Children often spend more time on technology at home than at school (Rideout & Robb, 2019). Recent research has underscored the importance of limiting screen time in early childhood education to promote healthy development, as excessive screen exposure may impede cognitive, social, and physical development (García et al., 2021; Lissak, 2018). Young children should prioritize high-quality, interactive content, such as educational videos and applications that encourage verbal responses or physical movement when it comes to their screen time (Panjeti-Madan & Ranganathan, 2023).

Teachers are responsible for guiding screen time usage, making sure the material being learned is age-appropriate and that device-based learning is dynamic, engaging, and meaningful (Pires et al., 2022). Many PSTs see the potential advantages of using technology within the classroom, particularly in terms of improving participation and providing varied methods to convey content (Beatty & Egan, 2020). Some, however, have worries about children's excessive dependence on screens, particularly the influence on their psychological, social, and physical development (Muppalla et al., 2023). There is frequently a concern that screens may replace crucial personal relationships and hands-on learning experiences that are critical for young children's development (Canadian Pediatric Society & Digital Health Task Force, 2017). PSTs are also mindful of the need for clear standards and sufficient training on how to properly incorporate screen time within early childhood education.

3.2. Augmented and Virtual Reality

Augmented reality (AR) and virtual reality (VR) represent transformative technologies when utilized in education (Chang et al., 2022). AR involves overlaying digital content, such as images or information, onto the real world through devices like tablets and smartphones, promoting the real-world experience (Neumann et al., 2022). VR provides a fully immersive, computer-generated context in which users can interact with and explore new settings entirely removed from reality, often using headsets (Neumann et al., 2022).

PSTs express both enthusiasm and doubt about the integration of AR and VR into early childhood education (Taggart et al., 2023). Many PSTs recognize them as effective tools in diversifying the delivery methods related to pedagogy, making children engage more in learning. However, PSTs are also hindered by the limited or insufficient training they have received in integrating AR and VR into planning lessons (Tutkun, 2024). PSTs also report that it is necessary to understand how to merge AR/VR with existing curricula of early childhood education (Neumann et al., 2022). PSTs express additional concerns about how these tools increase the screen time of their students (Tutkun, 2024).

3.3. Digital Divide

The digital divide can be recognized as the discrepancy between individuals with easy and ready access to digital technologies and ways and those deprived of those privileges (Pásztor & Bak, 2020). Initially, the digital divide referred to a generational gap between older people (digital immigrants) and younger, digital natives who had access to and proficiency with technology (Ball et al., 2017). The digital divide can emerge in multiple domains, including access to technology and the internet; digital literacy, which is using

technology to access information; and digital assimilation, which is using technology in various aspects, including communication (Litchfield et al., 2021).

The digital divide reflects broader socio-economic disparities, as access to technology, training, and resources mirrors community opportunity gaps (Russo & Emtage, 2024). The COVID-19 pandemic underscored this divide, showing that merely providing technology did not enhance online learning (Golden et al., 2023). The divide often stems from how technology is used: White and affluent students tend to use it for creativity and problem-solving with more adult mentorship, while minority and low-income students often engage in routine drills with less support (Dubois et al., 2021). This disparity begins early, influenced by whether a school is public or private (Qayyum et al., 2024; Russo & Emtage, 2024).

3.4. Chat GPT

Released in November 2022, Chat Generative Pre-Trained Transformer (ChatGPT) is an advanced AI language model (Roose, 2022). It quickly gained popularity for its ease of use and ability to accomplish a wide variety of tasks across fields (İpek et al., 2023). Its interface is interactive and adaptable; because it utilizes natural language processing based on human language, it allows users to personalize their requests (Eysenbach, 2023).

Yet, almost as quickly as its popularity rose, questions also emerged about its ethical use, particularly within academic contexts, causing large school districts to ban it entirely (Zhang & Tur, 2024). ChatGPT has already become a controversial topic specifically due to its potential to assist the process of education through individualized task completions, immediate feedback, and support in tackling complicated subject areas (Montenegro-Rueda et al., 2023). While it is generally accepted that AI can be manipulated to support learning outcomes, especially in the process of acquisition of language, there is a notable unavailability of reliable data on how AI should be employed in the context of early childhood education (Yi et al., 2024).

ChatGPT has been increasingly integrated and used in teacher preparation programs to aid in tasks related to teaching (Robinson et al., 2023). For example, it has been used to help PSTs write lesson plans and develop student assignments (Karaköse & Tulubas, 2023) as well as developing objectives that can be used for specific grade levels and suggesting instructional activities (Sangkawet et al., 2020). PSTs have been able to utilize ChatGPT to generate prompts, design engaging project ideas, and develop worksheets that accommodate a variety of learning styles for student assignments (Sangkawet et al., 2020). ChatGPT can also simulate potential student questions or answers, allowing instructors to anticipate and prepare responses (Peterson & Basu, 2024). Like other forms of technology, PSTs have mixed feelings about ChatGPT. Many PSTs see advantages in using ChatGPT to save time (Montenegro-Rueda et al., 2023). Yet, Garrote Jurado et al. (2023) found that some teachers stress the need to monitor and guide students on the appropriate use of ChatGPT; many are wary of an overreliance on it.

3.5. The Current Study

Technology integration presents challenges for early childhood teachers, who must consider multiple aspects of children's development and education before selecting a particular piece of technology to integrate (Dong & Newman, 2016). While much literature was concerned with the amount of time children spend on devices (i.e., García et al., 2021; Muppalla et al., 2023), more recent research has revealed the complexities of technology integration (Nikolopoulou, 2021). For example, ChatGPT and VR headsets present opportunities for teachers to transform learning in exciting ways, yet research is lacking on how PSTs envision using these tools in their classrooms (Karaköse & Tulubas, 2023; Neumann

et al., 2022). Teacher preparation programs can provide PSTs with opportunities to grapple with these issues before they are out in the field teaching with the technology (Seufert et al., 2021; Vogt & Westerlin, 2021). To be sure, the use of case studies in teacher preparation courses presents ways to highlight issues related to technology integration, bringing out PSTs underlying feelings toward technology integration (Toogood, 2023; Wilson, 2023).

The purpose of this study is to use the SAMR model as a conceptual framework to explore how PSTs integrate technology. The use of case studies allowed PSTs the space to grapple with technology in more detail than a survey or questionnaire. The use of four separate case studies additionally allows for in-depth analysis across a semester, capturing differences between technologies or changes over time. This qualitative approach allows researchers to explore complex phenomena, like PSTs' feelings toward technology, with rich and detailed data from participants. Our specific research questions are as follows:

1. On what SAMR level do PSTs describe integrating technology in the given case studies?
2. How do PSTs describe technology?
3. What differences emerged, if any, in how PSTs described technology over time?

4. Materials and Methods

Data from this study were taken from a larger study exploring PSTs' beliefs about technology integration. This qualitative phenomenological research focused on how PSTs described their beliefs about various technology applications. The phenomenological paradigm is appropriate when researchers strive to describe, understand, and interpret the multiple realities of PSTs' experiences (Saldana, 2015). This study sought to understand the beliefs of PSTs. This qualitative approach sought internal reliability rather than generalizability (Merriam & Tisdell, 2015).

4.1. Context

Participants in this study included PSTs from one teacher preparation program in the southern United States. Our program is a bachelor's completion program in early childhood. Most participants attended a local community college before matriculating to our university for their final 2 years. Many of our students would be considered non-traditional students who are older, often work full-time, and attend school at night.

Our program is committed to technological integration. In partnership with Apple, we provide each student with an iPad at the beginning of their coursework to use as a student but also to use when facilitating lessons during their field placements. We have purposefully woven aspects of technology into many of our courses and assignments across the program. For example, throughout the program, students build a virtual classroom through Google Slides.

Students take a technology-based course at the beginning of their program. The course focuses on developing familiarity with multiple aspects of technology through hands-on exploration and critical analysis within an early childhood setting. Students visit Makerspaces, practice coding with Ozobots, and create art with Spheros. Students are introduced to the SAMR model early in the course as a framework for planning lessons.

4.2. Participants

This study included data from 11 participants, all female. A total of 63% of students were White (27% were Asian; 9% were Black). Convenience sampling was used in this study because all participants were students enrolled in the technology course that the first author taught. Demographic information about the students was not collected.

4.3. Data Collection Methods

The dataset includes students' responses to case study assignments students completed as part of their coursework. The assignment was presented to the students during class time, with some discussion. Then, students completed the assignment as homework. The case studies were designed by the first author based on issues relevant to early childhood preservice teachers. The case studies were focused on four scenarios: (1) appropriate recommendations for screen time in young children, (2) investing money in virtual reality, (3) access to technology as an equity issue, and (4) the use of Chat GPT in the classroom (see Table 2). The assignment was graded on a rubric for making connections to theories and research, evidence of critical thinking, and writing a clear thesis statement. Appendix A provides a sample of one of the case studies provided to students.

Table 2. Descriptions of case studies.

Case Study	Description
Developmental appropriateness of screen time	Imagine you are a teacher serving on your school's technology committee considering a 1:1 device initiative for students. What are your recommendations for what teachers should consider regarding how much technology to use in the classroom?
Is virtual reality appropriate for young children?	Imagine your school has just been given an \$18,000 grant. Write a proposal for how you would spend the money. You must decide between one of three options: (1) VR headsets, (2) other technology (3) dramatic play materials.
New Mexico: Education, access and the law	In 2018, Yazzie Martinez was a plaintiff suing the state of New Mexico for not providing adequate education to students. In 2021, she sued again to say that things had gotten worse since the pandemic. Write a letter to the local paper that contains your opinion as a local teacher.
Should ChatGPT be used in the classroom?	The teachers at your school are in a vigorous discussion about whether/how to use GPT with students. You are asked to weigh in. Should it be used? Is it considered cheating? What must the school consider before implementing Chat GPT?

All procedures performed in the study involving human participants followed the ethical standards of our institution's research committee (IRB approval no. 15593). Informed consent was obtained from all individual participants included in the study. Pseudonyms were used to ensure confidentiality.

4.4. Data Analysis

Students submitted their assignments through our University's LMS. This data were then downloaded from the LMS and uploaded into Dedoose for coding. Dedoose is a cloud application for managing, analyzing, and presenting qualitative and mixed-method research data (Version 9.2.221; Sociocultural Research Consultants, 2024). Data were coded through multiple cycles. In the first cycle, structural coding was used to capture participants' descriptions of technology integration (Saldana, 2015). Initially, the four structural codes used were substitution, augmentation, modification, and redefinition. However, we also found that participants at times simply listed kinds of technology rather than describing how it would be integrated. An additional code of "hardware" was added. We calculated the frequencies of each code for the different case studies. Additional first-cycle coding was done through emotion coding to label the emotions or feelings described by the technology use (Bazeley, 2020). For example, some participants described the positive effects of using technology on young children, while others expressed their own hesitations or fears for children in their technology use. These were often more general statements (i.e., talking

about technology integration in general) rather than being targeted toward a specific SAMR level.

5. Results

This study explored how PSTs described technology across four case studies. Students were able to describe technology integration most during the digital equity and the ChatGPT case studies (see Table 3). More students also described technology positively in those cases, while VR/AR had the most negative feelings. Finally, there were some changes over time. PSTs described technology most positively as the semester went on. ChatGPT, which was the last case study of the semester, was the only case study where PSTs described integrating technology in transformative ways.

Table 3. Code frequency.

	Screen Time	VR/AR	Digital Equity	Chat GPT
Hardware	2	6	1	0
Substitution	1	1	3	1
Augmentation	1	1	5	2
Modification	0	0	0	3
Redefinition	0	0	0	3
Positive Feelings	3	5	16	15
Negative Feelings	3	7	0	5

The results section will explore the themes that emerged in PSTs' technology integration and feelings toward technology by case. In the discussion section, we pull together themes across the case studies to answer the final research question about PSTs' attitude toward technology across the case studies.

5.1. Screen Time

This was the first case study assignment that students completed to gain an understanding of how PSTs view technology integration. Early childhood educators often hold negative views of technology and might wish to limit the time that students spend on screens in the classroom (Ross-Lightfoot et al., 2024). Many PSTs did not describe a specific use of technology, so it was difficult to determine how they envisioned integrating it into the classroom (see Table 4 for sample codes). For example, Samantha describes screen time as "various ways teachers can integrate technology into learning, such as computers, iPads, and phones". Hannah also describes "interactive and hands-on devices such as tablets with educational apps". Two students described technology integration with families, i.e., video chats and "well-designed e-books with limited distracting features that children read with parents".

We found that many had trepidations about using technology. Samantha writes, "technology overall is a great tool for teachers to use". Ashley similarly states, "educators should ensure children's safety by being hyper aware of websites. Preschool children should learn how technology applies to the world around them." There was one comment from Sarah that is reflective of many PSTs: although children may learn some concept[s] from watching educational programming, they learn better when there is physical interaction.

Table 4. Sample of codes for SAMR levels.

	Screen Time	VR/AR	Digital Equity	Chat GPT
Hardware	Various ways teachers can integrate technology into learning, such as using computers, iPads, and phones.	Tablets and laptops, when utilized effectively, serve as powerful tools to engage students actively in their learning process.	Access to technology includes more than just providing laptops or internet connections; it also means giving students the tools they need to thrive in an increasingly digital environment.	Not observed
Substitution	Infants and toddlers under 18 months can only use video chat with their parents or grandparents.		As a result, students need the internet and computers to complete their homework, quizzes, and assignments.	You could incorporate technology in the classroom with your students by taking turns asking questions and that may be fun for early childhood.
Augmentation	Make games or activities for their students or create lessons with which children can interact.	This VR/AR classroom is designed and set up for teachers to bring their classroom for special periods to engage or enhance what they are currently learning.	Educators can leverage digital tools to create engaging lesson plans, collaborate with peers, and provide timely feedback to students. In some restaurants, you have to scan a QR code to look at the menu, job applications are strictly online, and schools across the country are implementing virtual days throughout the school year.	
Modification	N/O	N/O	N/O	Chatbot can translate assignments into a student's native language.
Redefinition	N/O	N/O	N/O	It can also rewrite responses at different reading levels, making it easier for students to complete their assignments.
Positive Feelings		We cannot deny that VR and AR can create students' interest, increase students' engagement, and make them feel they are not in the classroom.	In today's interconnected world, technology is not just a supplementary tool; it is an integral part of modern education. It enhances students' learning experiences, fosters creativity, and prepares them for the challenges of the future workforce.	I would use ChatGPT appropriately as a teacher whether it is for myself to help with teaching, lesson planning, or communicating professionally with parents. I see this used positively in the classroom.
Negative Feelings	Students can misuse the electronics given to them if they are given too much freedom and time.	VR in the classrooms is damaging the relationships between students and overall human interaction.	Some people can support low-income families by donating school supplies to the school.	Although this site is good and quick to obtain an answer, it will be better for students not to use it in the classroom. They have a long future ahead; therefore, I would not recommend this site to students.

5.2. VR/AR

This case study was designed to examine whether VR/AR headsets could help PSTs describe technology integration more specifically. In the case study, participants were given imaginary funding and asked to purchase VR/AR headsets, general technology, or dramatic play materials. Most students (6) opted to purchase technology and listed kinds of technology to buy, rather than describing how it would be used. The SAMR level could

not be analyzed, e.g., “computers, headphones, keyboards, iPads, and even paid programs within these devices”.

Students described some of the positive benefits of VR/AR headsets. Emily describes headsets as being able to:

broaden students’ communication skills by having them build their own vocabulary by describing what they are seeing, create[ing] mathematical thinking by providing a hands-on approach to their reasoning and logical thinking skills, and enrich[ing] their experiences by giving them a visual aid to the context they are discussing and being taught in class.

For Hannah, headsets can “inspire students’ creativity and spark their imaginations...[it] can motivate them to explore new academic interests”. Finally, Jessica says that “we cannot deny that VR and AR can create students interest, increase students’ engagement and make them feel they are not in the classroom”. These positive sentiments are similar to research by Beatty and Egan (2020), where PSTs can see the educational benefits of technology use.

Students who opted to spend money on technology also had many positive things to say. Samantha describes the “efficiency of technology”, while Sarah states that “using technology has [an] impact on kids’ language development such as vocabulary and interacting with an adult”. For Madison, technology can “nurture students and their different learning styles”. Elizabeth returns to the idea of preparing children to use technology: By investing in technology, we empower our students with skills that are not only relevant but also indispensable in the digital age. Two students mentioned how technology could be used for teachers and students: “technology is the most useful for classroom either for students or teachers” (Sarah) and “technology is a great way to support students and staff” (Taylor).

Students also described the negative aspects of VR/AR. Many mentioned price being a barrier for the purchase of Smartboards or VR headsets that they were “a waste of money”. Madison goes on to state: If I have the budget to buy it, it does not mean I have the budget to maintain it”. Other than the cost, others were worried that VR headsets would not be used as often as Chromebooks or would only be used for content areas like science. Another student was worried about the potential isolation of using VR headsets, believing them to “damage[e] the relationships between students and overall human interactions”. VR/AR headsets could bring up security issues, as described by Jessica as a “potential risk of compromising user privacy”. Finally, one student mentioned that VR is “not including people with disabilities or sensory issues” (Samantha). More specifically, students “may feel uncomfortable or overwhelmed by the feeling of the VR headset so close to their face”. These concerns are in line with other studies where PSTs have listed cost, monitoring, and safety as barriers to using VR/AR headsets (Cooper et al., 2019).

5.3. *The Digital Divide*

The third case study presented is designed to highlight the digital divide. It included an overview of a legal case presented in New Mexico by a parent who believed that a lack of funding by the state department was causing unequal access to education (Lopez, 2023). She sued the state and won. In the meantime, the pandemic brought a new host of inequities to light because of the requirement of online learning and the lack of internet infrastructure in many rural New Mexico communities. The parents sued again and won. By presenting an example of the negative consequences of lack of access (including technology infrastructure), this case study is designed to add a layer to the technology debate—how can we argue for or against technology in our classrooms if we do not have access to it?

There were more examples on the augmentation level than previously and a few examples of substitution. PSTs advocated for technology in their responses, providing examples of how technology could improve access to educational resources. Ashley suggests substituting physical textbooks for online textbooks. Samantha states, “access to technology allows students to engage in online research, collaborate with classmates, and access educational resources beyond the confines of the traditional classroom”. Online resources can also be used to extend or expand children’s learning: high-speed internet allows students to search for the information they need, saving a lot of time compared to traditional textbooks (Jessica). Teachers may also use online tools to “create engaging lesson plans, collaborate with peers, and provide timely feedback to students” (Elizabeth). Two students mentioned virtual spaces—either virtual classrooms or virtual learning days, which could represent higher levels of the model depending upon the activity.

Many spoke positively of technology in describing the need for all to access it. Samantha writes, “the extension for technology relief would focus on the importance of equal access to education and the role of technology in bridging the gap among students”. On the theme of access, another student wrote: As an educator, I have seen the transformation in the power of access to technology. How technology can help achieve for students whether it is engagement, creativity, and academic success”. Another student highlights the implications of lack of access to technology affected learning: It became clear that a lack of access to technology put these children at a significant disadvantage, impeding their learning progress (Madison). Similarly, Samantha writes: the Yazzie Martinex case highlights the disparities in access to technology for students, which directly impacts their ability to fully participate in learning opportunities. Emily simply put, “being disconnected is a disadvantage”. Finally, one student described the importance of technology in preparing students: In today’s interconnected world, technology is not just a supplementary tool; it is an integral part of modern education. It enhances students’ learning experiences, fosters creativity, and prepares them for the challenges of the future workforce (Elizabeth).

The digital divide forced students to think about what access to technology looked like—challenging their conceptions that everyone had technology at home. Samantha notes, “In an age when technology is an essential part of learning, it is critical that all students have access to the resources they require to succeed”. Rather than providing hardware, teachers must ensure that students have access to how to effectively use the hardware. Madison states, “access to technology includes more than just providing laptops or internet connections; it also means giving students the tools they need to thrive in an increasingly digital environment”.

5.4. ChatGPT

The final case centered on the use of ChatGPT in the classroom. Before analyzing information from this case study, participants used ChatGPT; it was the first time some of them used it. The case study was focused on how, if at all, it should be used in the classroom. This aspect of technology saw the most diversity in SAMR responses (at every level) and more modification/redefinition levels. While it should be acknowledged that this case study was at the end of the semester, after PSTs had exposure to a variety of ways in which technology could be integrated (with and without ChatGPT), it was also interesting to note that PSTs also had many more positive comments about technology than negative comments (15 to 5).

Many PSTs included ways that they would use ChatGPT in their room that went beyond substituting. AI affords more possibilities than a worksheet. At the basic level, students described using ChatGPT for brainstorming ideas for class projects. Some talked about using it to generate “new paths for creativity and research. It can help them achieve

a greater grasp of the subjects they study” (Taylor). One student mentioned using AI in writing—from generating ideas to getting feedback, while another sees it as beneficial for assisting “DLL students in communicating with their peers”.

Others talked about the ethical implications of using ChatGPT and teaching students about its use: By incorporating lessons on proper research, attribution, and the ethical use of AI, I aim to equip students with the skills to navigate technology responsibly and ethically (Elizabeth)”. Jessica states, “instead of worrying about how students will negatively use it or ban the app, I will teach students how to use the app to enhance their knowledge”. Similarly, Hannah writes: despite concerns, educators should try the program and teach students how to use it responsibly. And later that “I would emphasize the importance of responsible and ethical use”. Ashley highlights an important theme for technology: ChatGPT is a good tool for the classroom when used appropriately.

In some of the positive comments, PSTs described how it could benefit their teaching. Madison writes, “I would use ChatGPT appropriately as a teacher whether it is for myself to help with teaching, lesson planning, or help communicating professionally with parents”. Elizabeth states, “I believe it also presents an opportunity to reshape how we assess and teach in the digital age”. Taylor states, “Staff members could benefit from ChatGPT and especially teachers!” Jessica describes using ChatGPT to generate lesson plans or create quizzes.

The negative comments highlighted safety concerns for students as well. Emily writes, “some of what ChatGPT puts out is plagiarized content”. Sarah believes that the rapid response rate of ChatGPT might limit students’ critical thinking: “they got [a] response right away, I believe that it decreases students’ abilities of critical thinking and their creative mind to write their answer down”. Hannah warns about the “potential risks of misuse or overreliance on ChatGPT”. Jessica is concerned about students writing, stating, “each time they use ChatGPT instead of using their own words they lose the opportunity to become better students”.

PSTs’ concerns and uses of AI are aligned with the literature on PSTs’ perceptions of AI use. For example, PSTs often focus on the technical dimensions of AI or view it from a security/safety standpoint without thinking about the social impact or how children may benefit from using AI, i.e., both moral sensitivity and social responsibility (Song & Ko, 2024).

6. Discussion

This study used case studies to explore PSTs’ views about technology across the semester during a class focused on technology integration. Yet, while many preservice teachers use technology (particularly for social media), they lack depth in using technology, particularly using technology in the classroom (Seufert et al., 2021). The results of this study highlight that PSTs expect to use technology with students—they view it as a “must” (Dong & Newman, 2016). Rather than viewing technology as a friend or foe, the PSTs grapple with how and when to use technology beyond whether to use it. Students have mixed views of technology use—highlighting both ethical and developmental issues. Although the PSTs feel like technology use is inevitable, they do not always feel equipped to use technology, nor are they able to highlight ways in which technology can be integrated into the SAMR model (Casey et al., 2023). Thus, reframing the question of whether or not to use technology as which technology and in what ways it should be used is essential in considering the themes across the case studies. This is in line with research that explores that it is not whether technology is used but *how* it is used that makes a difference in children’s learning and development (Nikolopoulou, 2021). Many PSTs believe in the

importance of technology in the classroom. Nevertheless, several barriers prevent PSTs from integrating technology in transformative ways.

6.1. *The Teacher's Role*

Across the cases, PSTs described their role in enabling technology in the classroom, which can be summarized as a facilitator, a provider, or a protector. Many PSTs described how technology could be used to enhance learning, which is in line with research on PSTs who believe technology can increase children's motivation and engagement (Brown et al., 2016). The use of digital technology is more appealing than pencil and paper tasks, so students may be more likely to complete the activity (Zipke et al., 2019). This was seen across all of these case studies. Nevertheless, most responses were categorized within the substitution or augmentation levels, suggesting that PSTs have ideas about using technology but lack skill in developing activities where students truly engage with it as a learning tool.

PSTs believe that technology use is inevitable, and as such, their role is to provide technology to prepare students for the digital world. Many students see their roles as helping students navigate issues of using technology (Mouronte-López et al., 2023). As such, using technology is an investment in students' future success (Taggart et al., 2023). For example, PSTs wanted students to be familiar with ChatGPT or VR to be competitive in a future workforce. Friedrichs (2015) similarly reported that technology usage was necessary to prepare children for the changing society in which they live. Yet, this is in some ways in tension with the SAMR model because exposure to various technologies could be accomplished at the lower levels. Simply exposing students to technology may not adequately prepare them to use technology effectively.

One other role that emerged through the case studies was that of a protector. Students grappled with the belief that students were constantly using technology and that they, as teachers, should protect students from it. PSTs believed that students were on screens at home, and their responses indicated that technology that the use of technology in schools was purposeful. Although this was evident in the VR/AR case study, it came through in other applications. In the literature, PSTs reported believing that technology was constantly being used and that schools should have a technology-free environment (Istemic Starčič et al., 2016). In some ways, this is in contradiction with their role as a provider of technology—how can PSTs limit screen time but also believe that they need to provide students with access to technology? The digital divide case study caused them to confront what may be a bias or assumption about whether young children had access to technology (Qayyum et al., 2024).

6.2. *Barriers to Technology Integration*

The use of case studies helps shed light on issues PSTs grapple with as they consider digital technology, AI, and early childhood education. While early childhood has traditionally been technology-averse, this study's findings highlight how PSTs consider when and how to use technology. While many believe technology is necessary and beneficial for students, they struggle to balance preparing children for the current technology landscape while supporting their growth and development overall. AI has complicated how teachers use digital technology in their classrooms. On the one hand, PSTs were excited about all the possibilities AI could afford in diversifying their lessons and helping automate teacher tasks. At the same time, they are hesitant to adopt AI more fully because they do not fully understand it.

The case studies revealed PSTs' beliefs about technology as well as how they imagined using it. Given that many PSTs described technology integration on the lower levels of

the SAMR model, it is important to consider what barriers may exist that prevent PSTs from imagining more transformative uses of technology. Tondeur et al. (2017) discuss potential barriers teachers face in technology integration as first and second-order barriers. First-order barriers include access to resources, training, and support, which may hinder teachers' technology integration. Many of the PSTs cited these first-order barriers when thinking about technology integration—accessing VR headsets, paying for technology equipment, and accessing the internet. These first-order barriers must be addressed before PSTs can integrate technology.

Second-order barriers include PSTs' feelings and beliefs about technology integration, which have an impact on how or how willing PSTs are to integrate technology into their lessons (Nikolopoulou, 2021). This study found several themes across the case studies that highlight PSTs' second-order beliefs, including the inevitableness of technology and the need to protect children from technology. Unlike prior research (i.e., Polly et al., 2010), PSTs did not cite a lack of support or confidence in using various technologies. PSTs seem to be ready to utilize technology in their classrooms but lack knowledge about how to do this more purposefully. This is a large knowledge gap that is the work of teacher preparation programs.

7. Conclusions

The study highlights several important considerations for teacher educators in supporting PSTs in navigating issues related to the intersection of AI, digital technology, and early childhood education. Cheek et al. (2019) highlight multiple layers that need to be utilized to ensure that PSTs are comfortable and confident in integrating technology. The first is to provide PSTs with technology experiences. In this research, when PSTs had direct experiences, as with ChatGPT, they were better able to think through technology as an instructional tool if they had first had experiences using it for personal use. Providing PSTs with experiences using VR headsets can enhance their understanding of their capacities. However, providing unplugged experiences can also go a long way in helping PSTs envision how technology can improve upon the skills or content development. Providing unplugged experiences can also help PSTs focus on the learner rather than the technology (i.e., how can I use these robots in my lesson vs. how can I teach computational thinking?).

In Cheek et al.'s (2019) second level, PSTs need preparation to use technology. On a program level, teacher preparation programs need to integrate technology more meaningfully across content areas to ensure that PSTs match content to pedagogical knowledge. PSTs will not leave one technology course with the skill necessary to engage in integration at the redefinition level. The literature highlights the continuous need for training and professional development beyond the education classroom (Sangkawet et al., 2020). While this is not a new idea, the results of this study (potential changes across the semester, but limited changes) reinforce the idea that PSTs need several experiences integrating technology to change second-order barriers. While the SAMR model provides a useful framework for teachers to use when considering technology, seeing multiple examples across content areas and age groups will extend PSTs' skills in selecting the technology that matches the objectives.

Cheek et al. (2019)'s last level is to use technology to build capacity and enhance learning, which might include enhanced coaching while PSTs are engaged in teaching with technology. This could include looking at video analysis of candidate instruction, live feedback using technological tools like Bluetooth earpieces, or simulations of teaching scenarios using virtual classrooms. In these examples, PSTs have opportunities to receive feedback in real-time on how they are teaching. Research utilizing these methods (as reported by Cheek et al.) showed that PSTs reported more confidence in their teaching

abilities using technology. These methods provide the potential to help address PST's second-order barriers and create more lasting change.

We would propose adding one contextual layer to Cheek et al.'s model. While PSTs must be provided practice with using technology, using technology for teaching, and using technology to improve teaching, we believe that technology itself is not objective. An important part of teacher education programs and technology courses is to raise awareness about the ethical issues related to technology use around the digital divide. COVID-19 highlighted disparities in access to hardware and internet connectivity (Catalano et al., 2021), and other research has shed light on how school districts, even with access to technology, do not integrate it equitably.

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Appendix A. Sample Case Study

[What] is Developmentally Appropriate Screen Time?

China is enacting legislation to limit children's screen time: <https://www.cnn.com/videos/world/2023/09/04/china-screen-time-limit-watson-dnt-lead-vpx.cnn> (accessed on 13 March 2025).

First, look at the recommendations from the following professional organizations:

- “Screen Time Recommendations for Children Under Six” Zero to Three (<https://www.zerotothree.org/resource/screen-time-recommendations-for-children-under-six/> (accessed on 13 March 2025)).
- What are some screen time guidelines for social media applications? American Academy of Pediatrics (<https://www.aap.org/en/patient-care/media-and-children/center-of-excellence-on-social-media-and-youth-mental-health/social-media-and-youth-mental-health-q-and-a-portal/middle-childhood/middle-childhood-questions/screen-time-guidelines/> (accessed on 13 March 2025)).
- “Screen Time and Children” American Academy of Child and Adolescent Psychiatry (https://www.aacap.org/AACAP/Families_and_Youth/Facts_for_Families/FFF-Guide/Children-And-Watching-TV-054.aspx#:~:text=Between%2018%20and%2024%20months,limit%20activities%20that%20include%20screens (accessed on 13 March 2025)).

Then, read NAEYC's position statement on technology, found here (https://www.naeyc.org/sites/default/files/globally-shared/downloads/PDFs/resources/position-statements/ps_technology.pdf (accessed on 13 March 2025)).

For your assignment:

You are serving as the teacher representative for your school's technology committee. The school is considering a 1:1 device initiative for students in all grade levels. What are your recommendations for what teachers need to consider regarding how much

technology should be integrated into the classroom? Think about your answer to the following questions:

- Should each grade level have a mandatory maximum or minimum of screen time per day?
- What kinds of technology should be provided for each grade level?
- How can we ensure that technology applications are high quality?

Here are some resources to get you started, but you may always want to do your own research. Skim the articles below to help formulate your opinion. There is no right/wrong answer; rather, the goal is to write an informed opinion.

Popular Press:

- Going Beyond Screen Time: “Using screen time and digital technology for learning: children and pre-teens” (<https://raisingchildren.net.au/school-age/school-learning/learning-ideas/screen-time-helps-children-learn#:~:text=Screen%20time%20can%20help%20children,to%20play%20games%20or%20apps> (accessed on 13 March 2025)).
- “5 ways screen time can benefit children and families” (<https://www.childtrends.org/publications/5-ways-screen-time-can-benefit-children-and-families> (accessed on 13 March 2025)).
- “The good, the bad and the ugly of children’s screen time during the COVID-19 pandemic” (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8444888/> (accessed on 13 March 2025)).

Professional Resources:

- PEW Research Center: Parenting Children in the Age of Screens (<https://www.pewresearch.org/internet/2020/07/28/parenting-children-in-the-age-of-screens/> (accessed on 13 March 2025)).
- The use of touch-screen tablets in early childhood: Children’s knowledge, skills and attitudes (<https://www.sciencedirect.com/science/article/pii/S0190740917310319> (accessed on 13 March 2025)).

Examples of district technology plans:

- Atlanta Public Schools (https://docs.google.com/document/d/1LChooT-STT2IVjD0tCczNpWY_eUATLphC-LXm9ft4xo/preview?tab=t.0 (accessed on 13 March 2025)).

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Article

Use of Instagram as an Educational Tool with Pre-Service Teachers and the Impact on Digital Competence in Communication and Collaboration

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Abstract: The rise of social media is transforming education by replacing traditional materials and promoting digital competence, a key area of focus in current training. Platforms like Instagram facilitate collaboration, access to learning, and content creation, becoming essential tools for the development of students and future educators in digital environments. This study aimed to enhance the digital competence of pre-service teachers, particularly in communication and collaboration, through Instagram as an educational tool. A quasi-experimental study with pretest and post-test measures was conducted, involving 391 students from the University of Granada. The results indicated an intermediate level of digital competence with improvements in both groups, though no significant differences were found between them. However, significant effects were observed in the intragroup analysis. The experimental group, which used Instagram as an educational tool for 11 weeks, showed improvements in communication and collaboration, digital content creation, and security. The control group also demonstrated progress, mainly in information search and problem-solving. These improvements align with previous studies, though the progress in the control group may be attributed to factors such as content focused on educational technology, student motivation, and engagement. This study confirms that social media can enhance digital competence as a learning tool.

Keywords: Instagram; social media; digital competence; higher education

1. Introduction

The increasing use of digital platforms, social networks, and technological tools is transforming teaching and learning methods, driving the replacement of traditional materials, such as paper, with more sustainable and digital alternatives. This transition not only contributes to reducing the ecological footprint but also enables educators to promote environmentally friendly practices by integrating digital materials into their classes (Gil-Quintana et al., 2020).

In this context, digital competence has become essential not only in the educational field but also in professional and personal spheres, as it facilitates communication, learning, and the exchange of information through platforms such as Instagram, Facebook, TikTok, and Twitter, which are widely preferred by students for social interaction (Jashari et al., 2022).

Digital competence is understood as a multifaceted ability encompassing the knowledge, skills, and attitudes essential for the effective use of information and communication technologies. This competence involves not only the technical ability to manage digital

tools but also the proactive willingness and attitude to use them competently in various contexts (Kallas & Pedaste, 2022).

Similarly, the impact of social networks on education is undeniable, as they have democratised access to educational content (Sobaih et al., 2022). Social networks are digital platforms that facilitate the creation of networks, communication, collaboration, and the exchange of user-generated content such as images, videos, and debates on public topics (Papademetriou et al., 2022).

Today, students can access school information in diverse formats, such as infographics, videos, animated images, and more, via the internet. Although the use of these tools offers new opportunities, it also presents logistical challenges, such as the preparation of electronic devices and the need for internet access and equipment like computers and projectors. However, platforms such as Facebook, with their intuitive design and ease of access via smartphones, optimise interaction without requiring complex infrastructure (Galván-Orozco et al., 2022).

Since the emergence of social networks, relationships between teachers and students have undergone significant changes. These platforms provide an ideal environment for creating educational content and fostering collaboration, allowing students to share and discuss ideas more dynamically (Rodríguez-Moreno et al., 2021). In particular, Instagram, launched in 2010 as an application for sharing images and videos, has established itself as an innovative educational tool. Its visual nature and ease of use make it a novel resource for education (Romero-Rodríguez et al., 2020). It also facilitates the creation and distribution of educational content, as demonstrated in an activity where students created posts about sustainable development using Instagram profiles and hashtags to increase the visibility of their posts (Robles-Moral & Fernández-Díaz, 2021). Moreover, Instagram facilitates the connection between skills developed in the classroom and literacy practices applied in real contexts, promoting creativity and the development of writing competences while offering a multimodal learning experience (Nasution, 2023).

To make effective use of social networks for learning purposes, digital competence is required. Consequently, there has been a significant increase in research focusing on digital competence in vocational training, prospective teachers, and university students (Barboudidis & Stiakakis, 2023; Estanyol et al., 2023; Guillén-Gámez & Mayorga-Fernández, 2020; McGarr & McDonagh, 2020; Palomeque-Córdova, 2020; Pegalajar-Palomino & Rodríguez-Torres, 2023; Sánchez-Caballé et al., 2020; Vázquez-Peñafiel et al., 2023).

As social network usage among the population grows, so does research exploring how these platforms can be leveraged for educational purposes (Pineda-Martínez & Puente-Torre, 2022). Social networks are increasingly being considered virtual learning environments where students can acquire and enhance their digital competence (Gil-Fernández & Calderón, 2021; Martínez-Sala & Alemany-Martínez, 2022). Studies also examine their use to promote digital competence and learning among future teachers, highlighting their growing relevance in educational training (Robles-Moral & Fernández-Díaz, 2021).

As noted, social networks are becoming more prominent in education, as they enable increased communication and collaboration, as well as the creation of content within teaching. They serve as learning tools and foster the use of information and communication technology (ICT) (Ansari & Khan, 2020; Haque et al., 2023). Additionally, collaborative work using social networks to improve digital competence promotes a more student-centred learning approach, enabling synchronous and asynchronous interaction and learning, which enhances motivation and academic performance (Cendrero-Ramos & Valverde-Berrocso, 2024).

Thus, the link between the use of social networks and digital competence is of interest for investigation, with studies corroborating the increase in digital competence levels after

using social networks as collaborative learning tools, highlighting Instagram as a tool (Fardiah et al., 2023; Liu et al., 2022).

Therefore, these networks are employed linked to Area 2 of the Digital Competence Framework for Citizenship in its version 2.2 (DigComp 2.2), focused on communication and collaboration through digital technologies. It should be noted that this framework includes five areas—searching and managing information and data (formerly known as information and media literacy); communication and collaboration; content creation; safety; and problem-solving (Vuorikari et al., 2022)—as well as Area 6.2, “communication, collaboration, and digital citizenship” in the Marco de Referencia de la Competencia Digital Docente 2022 [Framework of Reference for the Digital Teaching Competence] (MRCDD) (INTEF, 2022).

Aligned with the growing use of social networks in education, the objective of this study was to develop the level of digital competence, primarily in communication and collaboration, of pre-service teachers through the use of Instagram as an educational tool.

In line with the literature, the hypothesis is proposed that the use of Instagram as an educational tool in the initial teacher training will significantly improve the digital competence of the students in the experimental group compared to the control group, particularly in the areas of communication and collaboration.

2. Method

This study employed a quantitative research method, applying a quasi-experimental design with pretest and post-test measurements and a non-equivalent control group (Waddington et al., 2022). The variables considered in this study were (a) the independent variable, which was the participation or non-participation in practical sessions using Instagram as a techno-pedagogical tool; (b) the dependent variable, which was the digital competence of the participants; and (c) the descriptive variables, including sociodemographic aspects (age, sex) and issues regarding the use of social networks and ICT (time spent on social media for educational or non-educational purposes, followed accounts on social networks, prior ICT training, and age of starting social media use).

The sample was selected through a non-probability procedure, specifically using a convenience method (Andrade, 2021). The groups included in this study have a natural composition, as they correspond to the eight groups that make up the second year of the Primary Education degree at the University of Granada. The treatment assignment, i.e., the implementation of the sessions through Instagram, was carried out in three experimental groups, selected based on their accessibility.

Thus, it was ensured that the groups were comparable, as similar groups can be compared (Grimes & Schulz, 2002). To reduce the risk of selection bias due to convenience sampling in a quasi-experimental non-probabilistic study, the groups were compared based on key aspects: age range, sex, course, subject, content, and pretest results.

2.1. Participants

The sample consisted of students from the Primary Education Degree at the University of Granada enrolled in the course “Technological Resources Applied to Primary Education”, which took place in the first semester of the 2023/2024 academic year. They were asked to complete a questionnaire that included questions about sociodemographic characteristics and a self-assessment test to evaluate their digital competence. Before starting, they received information about the purpose of this study and the confidentiality of their data. They were also asked for informed consent to participate. This study was approved by the Ethics Committee of the University of Granada (registration number: 3474/CEIH/2023). Data collection took place between September and December 2023.

Specifically, the final sample consisted of 391 participants, with 286 women (EG = 125; CG = 161) and 105 men (EG = 47; CG = 58), aged between 18 and 25 years ($M = 19.36$; $SD = 1.135$). For the classification of age in this study, two categories were defined according to the World Health Organisation (WHO, 2024): adolescents, including those aged 19 or younger, and young adults, aged 20 to 25 years. Table 1 provides additional details about the sociodemographic characteristics of the participants.

Table 1. Sociodemographic data.

Variables	Total		EG		CG	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Sex						
Male	105	26.9	47	27.3	58	26.5
Female	286	73.1	125	72.7	161	73.5
Age						
≤19	289	73.9	138	80.2	151	68.9
20–25	102	26.1	34	19.8	68	31.1
Daily social media use						
No social media use	0.0	0.0	0.0	0.0	0.0	0.0
1 h or less	12	3.1	6	3.5	6	2.7
Between 1 and less than 4 h	172	44	77	44.8	95	43.4
Between 4 and less than 6 h	140	35.8	52	30.2	88	40.2
Between 6 and less than 8 h	56	14.3	31	18.0	25	11.4
More than 8 h	11	2.8	6	3.5	5	2.3
Daily social media use for educational purposes						
No social media use for educational purposes	30	7.7	13	7.6	17	7.8
1 h or less	235	60.1	107	62.2	128	58.4
Between 1 and less than 4 h	107	27.4	43	25.0	64	29.2
Between 4 and less than 6 h	16	4.1	8	4.7	8	3.7
Between 6 and less than 8 h	2	0.5	1	0.6	1	0.5
More than 8 h	1	0.3	0.0	0.0	1	0.5
Follows educational content accounts on social media						
Yes	159	40.7	68	39.5	91	41.6
No	232	59.3	104	60.5	128	58.4
Has prior ICT training						
Yes	129	33	48	27.9	81	37
No	262	67	124	72.1	138	63
Age of starting social media use						
6–12	176	45	77	44.8	99	45.2
13–15	196	50.1	88	51.2	108	49.3
16–18	19	4.9	7	4.1	12	5.5

Note. The age classification for the use of social media follows the educational stage categories in Spain: Primary Education (6–12 years), Secondary Education (13–15 years), and High School (16–18 years) (Ministerio de Educación, Formación Profesional y Deportes [Ministry of Education, Vocational Training, and Sports], 2023).

2.2. Data Collection Instrument

The pretest and post-test evaluation of digital competence was carried out using the self-assessment test of digital competences for citizens in Andalusia, developed by the Digital Agency of the Junta de Andalucía (2018). This instrument is aligned with the principles of the DigComp 2.2 framework, which identifies five key areas of digital

competence: information and data management (formerly known as information and media literacy), communication and collaboration, content creation, security, and problem-solving. These areas are the same ones addressed in the test, which is organised into five main competence blocks.

The test consists of 21 competences distributed across various tasks, ranging from 21 to 63 items. These tasks include different types of questions, such as multiple-choice, image selection, scales, drag-and-drop, matching, sorting, and practical simulations. The item scores are scaled from 1 to 4, corresponding to competence levels, so the results of the test can range from 21 to 84 points, where higher scores indicate a higher level of digital competence. To classify the results, the scores are grouped into four levels: preliminary, initial, intermediate, and advanced.

This instrument has been previously used in other studies, where it showed good psychometric properties and internal consistency (Contreras-Germán et al., 2019; Ibáñez-Cubillas, 2021). In this study, reliability was tested using Cronbach's alpha coefficient for the pretest measures (CG $\alpha = 0.708$; EG $\alpha = 0.754$) and post-test (CG $\alpha = 0.754$; EG $\alpha = 0.786$), which indicates adequate reliability.

2.3. Procedures and Materials

The intervention with Instagram carried out with the experimental group was developed over 11 weeks during the weekly, in-person practical sessions of the course, although some tasks also continued outside the classroom to encourage the educational use of social media. The purpose of the sessions was to carry out the practical tasks specific to the course, using Instagram as an educational tool.

Regarding the duration of the intervention, various studies on the use of social networks with a positive impact on learning indicate that an optimal period ranges between 4 and 12 weeks to ensure the effectiveness of such initiatives (Salas-Rueda & Salas-Rueda, 2019; Zulkifli et al., 2018).

On the other hand, the intervention was structured in different phases, following the approach commonly used in many studies that integrate social networks into educational contexts (Alexiou & Paraskeva, 2020; Almarzouki et al., 2022).

Thus, the activities were designed based on the book by Aznar-Díaz et al. (2021), adapting them in line with research highlighting the suitability of social networks as technopedagogical tools (Almarzouki et al., 2022; Gómez-García et al., 2015). Furthermore, the inclusion of reflections, comments, and debates developed through the social network was prioritised (Demirbilek & Talan, 2018; Pérez-Suasnavas & Cela, 2022).

Similarly, the intervention was structured in two phases:

- Phase 1 (Week 1): workgroups were formed, and training was provided on the educational use of Instagram. Additionally, the Instagram account for the course was presented, where weekly tasks were incorporated. Students also created Instagram accounts, assigning them a name and group number, and optimised their visual presentation (Figure 1).
- Phase 2 (Weeks 2–11): students worked collaboratively using Instagram to complete tasks related to the course content from the book by Aznar-Díaz et al. (2021). This phase encouraged debates, content creation in different formats, feedback, and reflection, with Instagram being the only tool used for activities.

The control group worked on the same content from the book by Aznar-Díaz et al. (2021), carrying out corresponding practical activities through collaborative work, but without using social networks. These activities consisted of solving practical problems related to course content, searching for information, and writing theoretical papers, as well as classroom debates, conducted through the use of traditional text writing tools or

PowerPoint presentations or similar tools. Feedback was provided directly by the teacher during practical sessions.

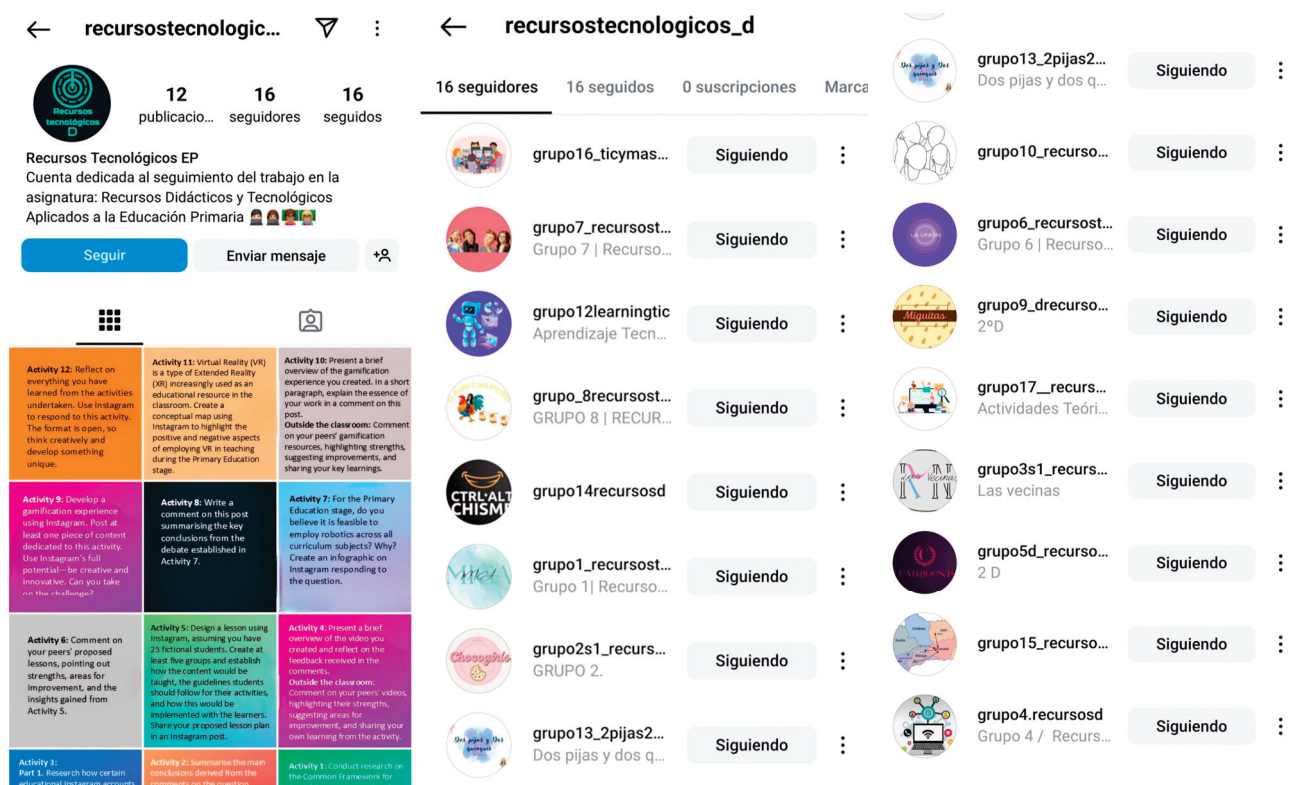


Figure 1. Evidence of the course Instagram account and student accounts.

The sessions and timing for the control group were identical to those of the experimental group, with a weekly structure that included a two-hour practical session. To ensure comparable conditions between the groups, the same content, duration, and format of activities were maintained in both cases, with the only difference being the use of the Instagram social network as an educational tool in the experimental group.

Measures were taken to minimise contamination between the groups. Students were not explicitly informed about the specific objectives of this study related to the use of Instagram to avoid bias. Moreover, it was not indicated whether they belonged to the control or experimental group.

It should be noted that, before starting the sessions, both groups took the pretest, which took place on 21 September 2023. Then, at the end of the practical sessions, the post-test was applied on 14 December 2023.

2.4. Data Analysis

For the data analysis, IBM SPSS version 28 was used. The normality of the distribution of scores was first assessed using the Kolmogorov–Smirnov test, with the Lilliefors significance correction, which allowed us to determine whether the variables followed a normal distribution.

Next, the relevant descriptive statistics, such as means and standard deviations, were calculated to provide an overview of the data. Significant differences between sociodemographic factors were also investigated using the Mann–Whitney U test for dichotomous variables (sex, number of social networks, educational account subscriptions, and prior training) and the Kruskal–Wallis H test for variables with more than two categories (age, social media use, age of starting social media use).

To test the proposed hypothesis, statistical tests were applied for group comparisons, with the Mann–Whitney U test being used for pretest and post-test to determine whether there were differences between the control and experimental groups. For intragroup comparisons, the Wilcoxon signed-rank test was used to compare the scores obtained by the groups at the two evaluation points.

3. Results

The normality analysis using the Kolmogorov–Smirnov test, adjusted with the Lilliefors significance correction, showed that the data did not follow a normal distribution, as the p -value was less than 0.05 for both the pretest measurement ($K-S = 0.099$; $df = 391$; $p \leq 0.001$) and the post-test ($K-S = 0.065$; $df = 391$; $p \leq 0.001$).

The results obtained from the comparisons between student groups based on their sociodemographic factors in the pretest phase indicate that, overall, no significant differences were identified in most of the variables assessed (Table 2). However, several prominent patterns were observed in the groups. Men in the experimental group obtained the highest mean score ($M = 46.87$), followed by men in the control group ($M = 44.91$). Regarding age, students in the experimental group aged 19 or younger had a higher mean score ($M = 45.22$), while in the control group, those aged 20–25 recorded the highest score ($M = 45.31$). Additionally, students in the experimental group who used social media between 4 and 6 h a day obtained the highest scores, particularly in educational use ($M = 48.63$). It was also noted that students with prior training in technology in the experimental group had a significantly higher score ($M = 49.25$). The mean scores of the experimental and control groups based on age of starting social media use were higher for those aged 16 to 18, with the experimental group having higher scores ($M = 49.86$).

Table 2. Differences between groups based on their sociodemographic factors.

Sociodemographic Data/Group	<i>n</i>	<i>M</i>	<i>SD</i>	<i>U/H</i>	<i>p</i>
Sex					
Experimental					
Male	47	46.87	10.350	U = 2498	0.130
Female	125	44.58	7.363		
Control					
Male	58	44.91	6.926	U = 4040.5	0.131
Female	161	43.86	8.140		
Age					
Experimental					
≤19	138	45.22	8.035	U = 2342.5	0.989
20–25	34	45.15	9.510		
Control					
≤19	151	43.61	7.826	U = 4434	0.106
20–25	68	45.31	7.785		
Daily social media use					
Experimental					
No use	0	0.00	0.000	H = 3.443	0.487
1 h or less	6	45.00	2.530		
Between 1 and less than 4 h	77	44.47	8.021		
Between 4 and less than 6 h	52	46.65	9.154		
Between 6 and less than 8 h	31	45.29	8.715		
More than 8 h	6	41.83	5.231		

Table 2. Cont.

Sociodemographic Data/Group	<i>n</i>	<i>M</i>	<i>SD</i>	<i>U/H</i>	<i>p</i>
Control					
No use	0	0.00	0.000	H = 1.289	0.863
1 h or less	6	45.17	4.956		
Between 1 and less than 4 h	95	43.83	8.870		
Between 4 and less than 6 h	88	44.58	7.342		
Between 6 and less than 8 h	25	43.36	6.714		
More than 8 h	5	44.80	3.347		
Daily social media use for educational purposes					
Experimental					
No use	13	43.62	6.923	H = 1.863	0.761
1 h or less	107	45.25	7.581		
Between 1 and less than 4 h	43	45.00	10.095		
Between 4 and less than 6 h	8	48.63	10.309		
Between 6 and less than 8 h	1				
More than 8 h	0	0.00	0.000		
Control					
No use	17	46.24	11.654	H = 3.101	0.684
1 h or less	128	44.45	6.964		
Between 1 and less than 4 h	64	43.27	8.463		
Between 4 and less than 6 h	8	42.88	6.917		
Between 6 and less than 8 h	1				
More than 8 h	1				
Follows educational content accounts on social media					
Experimental					
Yes	68	45.81	9.987	U = 3392.5	0.653
No	104	44.81	7.041		
Control					
Yes	91	43.95	7.466	U = 5796.5	0.952
No	128	44.27	8.114		
Has prior ICT training					
Experimental					
Yes	48	49.25	10.708	U = 2083.5	0.002 **
No	124	43.64	6.596		
Control					
Yes	81	45.32	7.247	U = 4743.5	0.061
No	138	43.44	8.106		
Age of starting social media use					
Experimental					
6–12	77	45.26	8.614	H = 2.496	0.287
13–15	88	44.78	7.959		
16–18	7	49.86	9.245		
Control					
6–12	99	43.96	7.170	H = 0.148	0.928
13–15	108	44.23	8.705		
16–18	12	44.75	4.575		

Note. Significance level: ** $p < 0.01$.

For the intragroup comparison in the experimental group, the mean score increased from ($M = 45.20$) in the pretest to ($M = 52.23$) in the post-test, while in the control group, it increased from ($M = 44.14$) in the pretest to ($M = 51.71$) in the post-test, with the effect size being slightly greater in the experimental group ($r = -1.226$) compared to the control

group ($r = -1.225$). These results indicate an intermediate level of digital competence. As for the hypothesis, it can be partially accepted, as the mean score has increased, although no significant intergroup differences were found (Table 3).

Table 3. Intragroup and intergroup comparisons.

Group/Measure	<i>n</i>	<i>M</i>	<i>SD</i>	<i>z</i>	<i>p</i>	<i>r</i>
Intragroup						
Experimental						
Pretest	172	45.20	8.317	−16.077	<0.001 ***	−1.226
Post-test	172	52.23	9.486			
Control						
Pretest	219	44.14	7.835	−18.139	<0.001 ***	−1.225
Post-test	219	51.71	8.855			
Intergroup						
Pretest						
Experimental	172	45.20	8.317	−0.714	0.474	−0.036
Control	219	44.14	7.835			
Post-test						
Experimental	172	52.23	9.486	−0.374	0.708	−0.034
Control	219	51.71	8.855			

Note. Significance level: *** $p < 0.001$.

The mean scores obtained in the post-test were higher than those in the pretest in the experimental group, indicating an improvement in digital competence following the intervention with Instagram. Although the final score of the experimental group was higher than that of the control group, both groups experienced an increase in their scores, but this increase was not significant in either case (Figure 2).

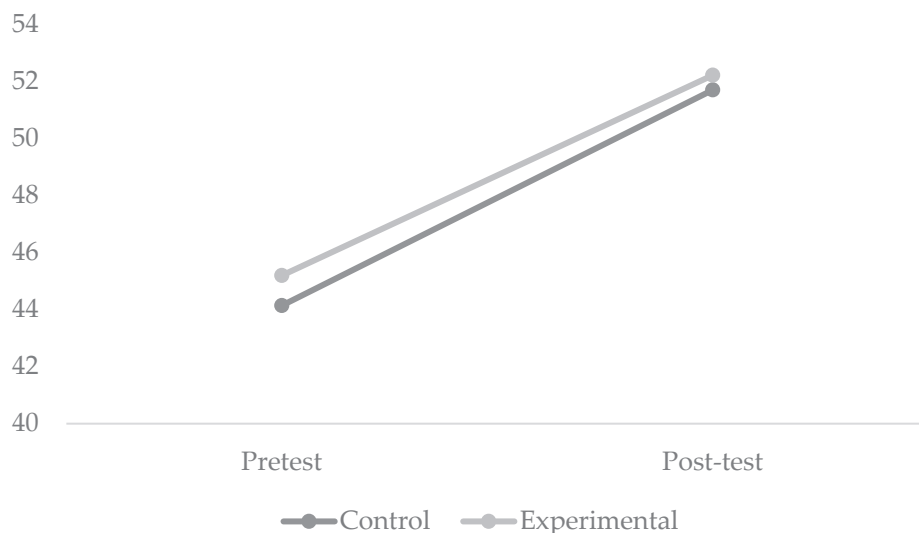


Figure 2. Comparison of the digital competence level between pretest and post-test measurements of the Instagram intervention.

In relation to the mean scores for each competence area, the highest values were observed in the following areas: Area 1 (information and data management) in the control group ($M = 7.36$); Area 2 (communication and collaboration) in the experimental group ($M = 14.40$); Area 3 (content creation) in the experimental group ($M = 10.25$); Area 4 (security) in the experimental group ($M = 10.72$); and Area 5 (problem-solving) in the control

group ($M = 9.94$). Significant differences were observed in Area 1, where the control group achieved a higher score than the experimental group ($p = 0.011$), while no significant differences were found in the other areas between the groups (Table 4).

Table 4. Intergroup comparisons by each dimension.

Competence Area	<i>n</i>	<i>M</i>	<i>SD</i>	<i>z</i>	<i>p</i>	<i>r</i>
Area 1						
Experimental	172	6.96	2.098	−2.528	0.011 *	0.128
Control	219	7.36	1.895			
Area 2						
Experimental	172	14.40	3.534	−0.484	0.629	0.024
Control	219	14.16	3.476			
Area 3						
Experimental	172	10.25	2.654	−1.445	0.149	0.073
Control	219	9.81	2.468			
Area 4						
Experimental	172	10.72	2.439	−1.230	0.219	0.062
Control	219	10.43	2.528			
Area 5						
Experimental	172	9.90	2.339	−0.213	0.831	0.011
Control	219	9.94	2.281			

Note. Significance level: * $p < 0.05$. Area 1 = information and data management (formerly known as information and media literacy); Area 2 = communication and collaboration; Area 3 = content creation; Area 4 = security; Area 5 = problem-solving.

4. Discussion

Digital competence results linked to sociodemographic factors present relevant data, focusing on age, sex, social media usage time, and prior ICT training. Regarding sex, male students show a slightly higher score compared to female students, consistent with previous studies (Pegalajar-Palomino & Rodríguez-Torres, 2023), although there are also studies where no difference is found between males and females (Estanyol et al., 2023). In terms of age, no significant differences were found, suggesting that the use of Instagram as an educational tool could be equally effective for university students, particularly those within the age range of 14 to 25 years, who are most active on social media (Robles-Moral & Fernández-Díaz, 2021).

However, the analysis of social media usage hours revealed that students in the experimental group who used Instagram between 4 and 6 h a day obtained the highest scores, in line with the results of the study by Mayor-Buzón et al. (2019), which identifies the intensity of social media use as an influential factor in competence.

In particular, students with prior training in the use of technology showed higher digital competence scores. This result aligns with studies that determine that prior knowledge of technology positively influences the educational use of digital tools, including social media (Barboutidis & Stiakakis, 2023).

In light of the results, an intermediate level of digital competence is identified both in the pretest and post-test after the intervention, although with higher scores. This level of competence is in line with research analysing the digital competence of university students (Guillén-Gámez & Mayorga-Fernández, 2020; Palomeque-Córdova, 2020; Sánchez-Caballé et al., 2020; Vázquez-Peñafiel et al., 2023). Meanwhile, some results indicate low digital competence among students who use social networks (McGarr & McDonagh, 2020).

The results obtained following the intervention with Instagram revealed that both the experimental group, which used Instagram, and the control group, which did not, experienced an improvement in their digital competence after the intervention. However, the scores of the experimental group were higher, and the effect size in the intragroup comparison was slightly higher and significant. Nevertheless, despite the increase in average scores in both groups, no significant differences were found in the intergroup comparison, suggesting that while the intervention might have had a positive impact, it was not robust enough to be statistically significant. For this reason, the hypothesis can be partially accepted.

In line with the improvement in digital competence, studies highlight that the experimental group, which used social media as a learning tool, improved their digital competence compared to the control group. Furthermore, the results verified the effectiveness of the designed teaching practices, especially in the experimental group, where collaboration and the use of Edmodo facilitated the cooperative and effective acquisition of digital competences (Martínez-Sala & Alemany-Martínez, 2022). Similarly, Rodríguez-Moreno et al. (2021) identified the improvement of digital competence in pre-service teachers using social media in learning, with collaborative work in networks being key (Cendrero-Ramos & Valverde-Berrocso, 2024; Galván-Orozco et al., 2022).

Moreover, Robles-Moral and Fernández-Díaz (2021) indicated that better learning outcomes were achieved after using Instagram, identifying it as essential for acquiring digital competence, and highlighting it as a learning tool that improved the participation of students who took a more active role (Pineda-Martínez & Puente-Torre, 2022). In this regard, Sobaih et al. (2022) demonstrated a positive and significant effect of social networks as online learning tools on students' academic performance.

It should be noted, however, that the general improvement in digital competence observed not only in the experimental group may be due to factors such as the following: knowing that students would be assessed (McCarney et al., 2007); the content of the course, which is linked to improving technological skills for teaching with technology (Martínez-Sala & Alemany-Martínez, 2022); the control group may have experienced a learning effect due to the repetition of the tests and familiarity with the test and experience (Fehringer, 2023); and the motivation of the students, their engagement with the work on social media, their attitudes towards technology, and the intensity of social media use are elements with the greatest capacity to predict digital competence in the use of social media (Gil-Fernández & Calderón, 2021; Mayor-Buzón et al., 2019).

At the same time, the lack of a significant effect may be due to factors such as the exposure time to working with social media, which might need to be longer to improve students' levels. Research by Means et al. (2013) indicates that in educational technology studies, the most significant effects are typically observed in prolonged interventions. Similarly, Tondeur et al. (2017) mention that the development of digital competences requires extended interventions, as participants need time to become familiar with digital tools.

Regarding the results by specific areas of digital competence, it was observed that the experimental group obtained better scores, although not significantly, in areas related to communication and collaboration, content creation, and security, while the control group excelled in information and data management and problem-solving. This could indicate that Instagram has a more direct impact on the areas that showed greater improvement, being the main skills needed to work with social media (Jashari et al., 2022; Robles-Moral & Fernández-Díaz, 2021; Rodríguez-Moreno et al., 2021).

5. Conclusions

This study highlights an intermediate level of digital competence among the students, with significant improvements observed following the intervention, particularly in the experimental group. Although both groups increased their scores, no significant intergroup differences were found. In terms of specific areas, communication and collaboration, content creation, and security were more strengthened in the experimental group, while the control group excelled in the areas of information and data management, as well as problem-solving. Additionally, sociodemographic factors such as intensive social media use (4–6 h daily) and prior ICT training showed a positive relationship with higher digital competence scores.

It is worth noting that the research was conducted with a specific sample of young university students, which limits the generalisation of the results to other educational contexts or populations. Furthermore, the improvements observed in both groups could be influenced by uncontrolled external factors, such as the learning effect resulting from the repetition of tests or the intrinsic motivation of participants towards the ICT topic. Moreover, the non-significant effect could be due to the need for more time using social media to identify improvements in digital competence.

Future lines of research could explore how the use of Instagram as a collaborative tool contributes to the conceptual, technical, and procedural elements necessary to foster digital competence. This would allow for the evaluation of whether it improves the connection between university education and teaching practice. In the long term, it would be useful to investigate whether this intervention impacts teaching performance and the integration of technologies in the classroom. Moreover, it should be studied how sociodemographic factors, such as sex or prior ICT experience, influence the benefits of the tool in different educational contexts.

Finally, this study confirms that social networks as a learning tool can improve digital competence. However, it is crucial to continue researching to optimise educational strategies and consider the influence of sociodemographic factors in the design of training programmes in order to maximise the effectiveness of teaching with social networks.

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Article

Designing Synchronous Online Learning and Teaching Lab: An Online Professional Development Program to Foster the Technical and Social Competences of Synchronous Online Teachers

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Abstract: Synchronous Online Teaching (SOT) is becoming increasingly popular, but research shows many teachers are inadequately prepared, calling for greater investment in professional development (PD). Additionally, there is a significant gap in research systematically describing the design of evidence-based PD initiatives. Consequently, researchers and educators lack an understanding of the essential components of these interventions, which obstructs the replication, dissemination, and implementation of evidence-based PD programs for synchronous online teachers. This study presents the design of SOL-lab, an online PD program aimed at fostering teachers' technical and social SOT competences. A detailed overview of the online PD design is offered, encompassing the underlying theoretical and empirical foundations, macro-level design principles, and micro-level instructional and learning activities. More particularly, three key design principles guided the online PD development process: focused observation of SOT, providing and receiving feedback, and stimulating the transfer of learning. By integrating authentic learning experiences and fostering reflective practice, our program aims to empower teachers with the necessary competences to thrive in SOT environments. An analysis of teachers' perceptions indicates that they had a positive experience with the effective features of the PD program. This study offers valuable insights for the development of effective online PD initiatives for SOT.

Keywords: teacher education; online professional development; instructional design; observational learning; feedback activities; transfer of learning; online teacher competences; synchronous online teaching; video conferencing

1. Introduction

Synchronous online education is witnessing a surge in popularity. While there has been a rise in asynchronous online learning and instruction from the nineties on, in the last decade more and more synchronous online education has been emerging too [1,2]. In the latter type of online education, teachers and learners engage directly through real-time video conferencing technology encompassing video, audio, or instant messaging [3]. However, teachers have generally not been adequately prepared to teach in this manner [1,4]. Recent research indicates that educators often lack confidence in their ability to effectively engage in synchronous online education [5], which leads to levels of distress [6]. Correspondingly, the latest report from the Teaching and Learning International Survey (TALIS) revealed that only 39% of educators in the European Union feel sufficiently equipped to integrate digital technologies into their daily educational practices [7,8]. Given the rapid evolvments in the educational landscape, this is a cause for concern, as teachers cannot remain behind, and they need to master the necessary competences to teach in an ever-changing society [9].

Not only are teachers themselves asking for more opportunities to enhance their professional development (PD) with respect to online education, but research also advocates for more investments in PD opportunities tailored for in-service teachers within the domain of online synchronous education [1,4,6]. In the present study, we describe the design of a PD program named SOL-lab (Synchronous Online Learning and teaching lab), which aims to foster synchronous online teaching (SOT) competences. Through the design of this program, our aim is to respond to the demand for more research-based PD opportunities for in-service synchronous online teachers.

1.1. Teachers' Technical and Social Synchronous Online Teaching Competences

Our PD program will be based on the SOT framework of Grammens et al. [10]. They define SOT competences as “the necessary knowledge, skills and attitudes to teach effectively in a synchronous online videoconferencing environment” [10] (p. 3). Based on a systematic literature review, they identified five teacher roles needed for teaching synchronously online: the instructional, managerial, technical, communicational, and social role. Each of these roles comprised several competence clusters, in which all competences found in the literature on SOT were bundled. More specifically, the PD program central to the present study, will focus on both the technical and social role. This focus stems from research indicating that the needs of teachers transitioning to synchronous online teaching are most pronounced in these areas [5,6,11]. Teachers often report difficulties in interacting with students online, making the students visible in the video conferencing environment, and establishing meaningful relationships online [5,6,12]. Additionally, the TALIS report confirms that the acquisition of digital teaching skills is one of the primary PD needs for teachers [8].

1.2. Key Features for Designing a Professional Development Program

Various studies in PD research focus on identifying the effective attributes of PD initiatives. This study employs the framework proposed by Merchie et al. [13] which is built upon frequently cited work in the field, including Desimone [14] and Van Veen, Zwart, and Meirink [15]. They define PD initiatives as “activities explicitly designed for and provided to educators or certified educational professionals with a focus on enhancing their own and their students' knowledge, skills, and attitudes” [13] (p. 2), which aligns with the perspective on PD in the present study. From their systematic review, Merchie et al. [13] identified nine characteristics of PD, which are well-documented in the literature for their efficacy. The more a PD initiative aligns with these characteristics, the greater the likelihood of a positive impact on participants' learning. The nine key features for the design of a PD program are described in Table 1.

Table 1. Key features for the design of a PD program [13] (pp. 6–7).

Key Features		Description
1	Content focus	The professional development (PD) needs to focus on the learning content
2	Pedagogical knowledge	The PD needs to focus on how to enhance teachers' competences
3	Coherent and evidence-based	The PD needs be coherent and informed by theory and evidence
4	Ownership	The PD needs to respond to teachers' self-identified needs and interests
5	Duration	The PD needs to be sufficiently extended and intensive
6	Collective or collaborative participation	The PD needs to be conducted in collaboration with internal and external peers
7	School- or site-based	The PD needs to be incorporated into teachers' daily work
8	Active learning	The PD needs to be inquiry-based
9	Trainer quality	The PD needs to be conducted by a trainer with sufficient knowledge and skills

1.3. Design of an Online Professional Development Program for SOT

Given the online nature of SOT and the advantages offered by online PD programs (e.g., being location-independent and indirectly supporting teachers' online teaching competencies), we have intentionally chosen an online PD program for this study. Despite the

growing number of online PD programs over the last decade, there has been insufficient emphasis on their design and delivery. Research highlights several design challenges associated with online PD, such as maintaining teachers' cognitive activation, keeping teachers focused, providing opportunities for reflection, and fostering interaction for exchanging knowledge, ideas, and experiences [16]. Recent studies have begun to investigate whether and how key elements of effective PD might be adapted for online settings [17]. Meyer [16] identified the fact that cognitive activation and collaboration were linked to both changes in teachers' practice and satisfaction with the online PD. Regarding collaboration, peer collaboration in a supportive social environment can foster a sense of belonging and shared learning experiences and provide chances for collaborative professional growth [12,17]. Additionally, teachers positively assess online PD when the courses are well-structured and have clear objectives [16].

During the COVID-19 pandemic, numerous studies aimed to identify teachers' PD needs as they transitioned from face-to-face instruction to synchronous online teaching (SOT) [5,6,11]. Additionally, a few promising examples of PD initiatives have already emerged [1,17,18]. While these initiatives were often limited in duration, focused solely on technical skills, or lacked a strong theoretical and evidence-based foundation, certain promising approaches have nonetheless emerged. Across these studies, three critical aspects of PD design can be identified in the context of SOT. First, different studies highlight the potential of observational learning within the context of SOT, given that the online format readily facilitates the use of recorded lesson videos. Research recommends integrating good teaching practices into PD initiatives, as teachers prefer video as their favored resource format and find it beneficial to access more exemplary practices [1,6]. Video observation offers teachers the chance to observe and assess teaching practices from various perspectives [1]. Second, video-based case studies can not only encourage self-reflection [1], but also foster collaboration among peers by sharing and reflecting on teaching practices and providing valuable peer feedback [18]. In the context of SOT, sharing experiences with colleagues, gaining inspiration, and receiving feedback are crucial for supporting teachers' PD [6] and enhancing their confidence [18]. Third, in addition to focused observation and providing and receiving feedback, research states that practical teaching experience is essential for mastering SOT [1]. Teachers request more teaching experience related to SOT, in addition to acquiring new knowledge and skills [6]. It is important to address this demand, as practical experience stimulates both teachers' proficiency and confidence in SOT [18]. Woodlands and Dart [18] emphasize the importance of offering low-stakes opportunities for teachers to become acquainted with the online video conferencing technologies and developing the confidence and skills necessary for teaching in their authentic teaching contexts.

Although these three critical aspects of PD design in the context of SOT have individually demonstrated their effectiveness in various studies, to our knowledge they have never been combined in a single online PD program until now. In our study, we will integrate these scientific insights by explicitly describing the design of our online PD program, including specific learning and instructional activities. While the ultimate goal is to examine the empirical validity of our online PD program—studying its impact by analyzing evidence and data supporting its effectiveness in achieving intended outcomes—this study initially focuses on evaluating the theoretical validity of the intervention. This involves systematically describing the design of the online PD program using the framework outlined by [19]. Additionally, we will integrate the nine key features of successful PD initiatives, as defined by Merchie and colleagues [13], into our PD program and assess teachers' experiences with these integrated features. In this way, we aim to address the research question: "Does the intervention adhere to the key features of successful PD design?"

2. Method

Framework for Describing Interventions

In the development of our PD program, we prioritize systematic research and clear guidelines to effectively support teacher change. There are two underlying ideas behind this approach. First, PD programs are often vaguely described. There is little information regarding the specific design of PD activities, i.e., which content is offered, and which instructional strategies and learning activities are taking place [19,20]. Second, PD programs are frequently developed without thorough consideration of whether specific research-based practices effectively translate to online environments [17,21]. Therefore, research advocates for rigorous empirical studies that meticulously examine the design elements of online PD programs [14,21,22]. In alignment with this perspective, Bouwer and De Smedt [19] emphasized the need for more detailed descriptions of intervention studies in general, with the twofold aim of theory building in specific fields and the dissemination of intervention programs in educational practice. Therefore, we will use their framework to describe our intervention. The framework of Bouwer and De Smedt [19] comprises four key elements that outline the design of an intervention: (1) the context of the intervention, (2) the theoretical and/or empirical grounding, (3) the macro- (or program) level design principles, and (4) the micro-level description of the instructional activities, learning activities, and instructional materials.

The first component, the context of the intervention, pertains to the national context, target group, prevailing decrees, and the individual(s) delivering the intervention. The specific context in which an intervention is implemented significantly shapes the selection of design principles. This aligns with the framework of Merchie and colleagues [13] which emphasizes the importance of considering both contextual factors and the personal characteristics of participants when implementing and sustaining a successful PD initiative. The second component of the framework proposed by Bouwer and De Smedt [19] delves into the theoretical and empirical rationale that underpins the intervention and further elucidates the relationship between the instructional activities and learning activities, as well as between the learning activities and the expected learning outcomes [20]. For example, if we want to stimulate the transfer of newly acquired SOT knowledge into teachers' practice (learning outcomes), we need to support teachers in transferring the information presented in an instruction video into their own practice (instructional activity), so they can reflect on this newly acquired knowledge (learning activity). Following a comprehensive analysis of the context and theoretical and empirical grounding of an intervention, the third component is the formulation of key design principles that form the crucial ingredients underlying an intervention [19]. More specifically, the third component encompasses the macro- (or program) level design principles, including the focus (i.e., the main content of the instruction), the mode (i.e., how instructions are provided to the learners), and the sequence of the intervention [19] (p. 127). Given the close interconnection between the theoretical and empirical foundations, and the macro-level design principles of the intervention, we collectively discuss these components according to the learning outcomes of SOL-lab. Lastly, the fourth component emphasizes a detailed, micro-level description of the instructional activities, learning activities, and instructional materials. An exemplary selection of instructional materials is provided in Figure A1 in Appendix A.

During the design of SOL-lab, we consistently used the nine key elements of effective PD initiatives as fundamental criteria to guide our development process [13]. We also made deliberate decisions to address the specific challenges associated with online PD [16]. Finally, we evaluate to what extent teachers have experienced the nine key features for effective PD, as described by Merchie et al. [13]. After successfully completing SOL-lab, teachers' perceptions regarding the degree of integration of these core PD features into the program were collected, both quantitatively, through statements, and qualitatively, through open-ended questions and an in-depth interview. We conduct a descriptive analysis of the 9-point Likert scores that the teachers provided on statements linked to the nine key features for designing a PD program, as outlined by Merchie and colleagues [13]. For the

responses to open-ended questions and the content of the interviews, a thematic analysis is applied.

3. Results

3.1. Context of the Intervention

3.1.1. Context and Aim of SOL-Lab

The aim of the online PD program SOL-lab is to enhance teachers' technical and social SOT competences through an online PD program. In Flanders (Belgium), and, by extension, in Europe, online education is not yet structurally integrated into the educational landscape, as it is in some larger countries such as Australia or Canada. In crises circumstances, such as the COVID-19 pandemic, teachers, especially those in primary and secondary education, are not prepared to smoothly transition to an online mode of delivering instruction. Instead, they often resort to a form of emergency remote teaching [4]. Although online education could be better organized and implemented during that period, the Flemish government also saw benefits associated with it, which resulted in the provision of a legal framework on how schools, even outside of crisis situations, can use online learning in the classroom. Since 2023, the Flemish government has approved a decree whereby a specific percentage (ranging from 20% to 40%, depending on the grade) of each study program in secondary education may be offered through interactive distance education. However, since this legal framework has only recently come into effect, online education has not yet been widely implemented in schools. Despite synchronous online learning being recognized as an emerging and promising form of online distance education, there is a noticeable lack of implementation in the field. Furthermore, while recent research underscores the importance of specific pedagogical competences for effective SOT [10], there remains a notable discrepancy between the demand for and the accessibility of research and PD initiatives focusing on SOT [2,23,24].

3.1.2. Target Group of SOL-Lab

The online PD program was customized for synchronous online in-service teachers employed by d-teach, a Flemish organization providing online education to learners of all ages, primarily one-to-one or in small-group synchronous settings. Most of the participants reside worldwide, though others live in Belgium. All participants ($N = 17$) were qualified teachers, i.e., they previously earned a teacher training degree. The teachers' average age was 40 years ($SD = 10$, range: 29–63), and they had on average 4 years ($SD = 4$, range: 0–13) of online teaching experience. They had experience across diverse educational levels and disciplines, including nursery, primary education, and secondary education, as well as speech therapy. All teachers voluntarily participated in the PD program, which they were invited to, and which was offered to them free of charge. Upon completion of the PD program, they received a modest monetary incentive. In view of ecological validity, the intervention was led by the PD leader of d-teach. The PD leader is also the first author of this paper.

3.2. Theoretical and Empirical Grounding of the Macro-Level Design Principles of SOL-Lab, According to the Learning Outcomes of the PD Program

In the following paragraphs, we will outline the theoretical and empirical foundations underlying the online video-based PD program SOL-lab, as well as the corresponding macro-level design principles that were integrated into the program, according to the learning outcomes of the PD program. More particularly, we will elaborate on (1) learning outcomes of SOL-lab, namely teacher roles and competences for teaching synchronously online—derived from the SOT framework of Grammens et al. [10], (2) the first design principle, which involves focused observation of SOT—derived from the social learning theory of Bandura [25], (3) the second design principle, which involves providing and receiving feedback—derived from the power of feedback [26], and (4) the third design principle, which involves stimulating the transfer of learning [27]. Figure 1 provides an

overview of the theoretical and empirical grounding of the macro-level design principles, the associated micro-level descriptions (including teaching and learning activities) which we will detail below, and the intended learning outcomes of the PD program SOL-lab.



Figure 1. Overview of the theoretical and empirical grounding, macro-level design principles, micro-level descriptions, and intended learning outcomes of the PD program SOL-lab [25–27].

3.2.1. Learning Outcomes of SOL-Lab: Teacher Roles and Competences for Teaching Synchronously Online

The aims of the PD program, and thus the learning outcomes of SOL-lab, are to enhance teachers' technical and social SOT role. Teachers need to feel supported to improve student learning as they teach online. Despite the increasing demand and supply of online education, evidence-based PD initiatives aimed at bolstering teachers' SOT competences lag behind [2,28]. In this study, we will adhere to the framework of Grammens et al. [10] for SOT competences which was established through a systematic review study. This SOT framework consists of five roles: the instructional, managerial, technical, communicational, and social role. Each role is a combination of different competence clusters. Although each role is equally important, teachers pointed out that they especially experience a deficiency in fulfilling their technical and social role as a synchronous online teacher [5,6,11]. More specifically, teachers requested additional support and training on how to manage the technical aspects of the virtual learning environment and select the appropriate digital tool [8]. They also sought guidance on how to promote social interactions and cultivate sustainable relations online [5,6,12]. These specific skills necessitate comprehensive PD for teachers within authentic learning contexts [1,4,6]. Therefore, the technical and social role, as presented in Figure 1, together with their competence clusters, were selected as the learning outcomes for our PD. If we aim to provide teachers with opportunities for growth and learning, we must equip them with new expertise, support and feedback in the synchronous online learning environment [9]. Teachers require training to enhance their practice effectively on one hand and to cultivate greater confidence on the other hand [5].

3.2.2. Design Principle 1: Focused Observation of SOT

The first design principle that underpins our PD program is derived from the social learning theory of Bandura [25]. Peer observation, a key aspect of observational learning, has been identified as a valuable tool in the context of SOT. Research highlights the fact that teachers report significant learning experiences from observing their peers when venturing into online teaching for the first time [1,6,29]. This finding resonates with Bandura's social learning theory [25], which emphasizes the pivotal role of observation, modeling, and imitating in acquiring new knowledge and skills. Bandura's theory [25] suggests that teachers can enhance their SOT abilities by observing the behaviors of other SOT practitioners and witnessing the consequences of these observed behaviors. If the consequences are positive, a vicarious experience is generated in the observer, which enhances the development of a cognitive structure. This leads to the expectation that performing the observed behavior oneself will also result in positive outcomes, eventually leading to the emulation of the other SOT practitioners' actions. Therefore, teachers should be able to observe the teaching practices of other SOT teachers in our PD program. In this way, teachers can repetitively view various authentic teaching practices from various perspectives while reflection is triggered [30–32]. This is important, as observing and analyzing teaching practices in depth enhances teachers' practice [33]. However, it is crucial to recognize that social learning is an active rather than passive process, and effective learning may not always result solely from observation. Internal cognitive processes also significantly influence learning outcomes. According to Bandura [34], four conditions are necessary for learning observation: attention (i.e., focusing on teachers' behavior), retention (i.e., remembering teachers' behavior), reproduction (i.e., performing the observed behavior), and motivation (i.e., being willing to copy the behavior). In addressing this last condition, teachers engage in a mental comparison between the observed teaching behaviors and their own instructional practices [35]. Such observations can provide valuable evidence regarding the effectiveness of specific teaching approaches, especially within the same target audience and instructional context. Therefore, in our PD program, we aim to provide good practices that closely mirror the authentic teaching practice of the teacher. The four conditions guided the design of our intervention.

Beyond observing others, reflecting on one's own actions and seeing oneself in action is a potential tool for PD that promotes the enhancement of teachers' competence [36]. Self-observation provides individuals with the opportunity to deliberately observe themselves from different perspectives, potentially identifying aspects of their teaching practice that they were not consciously aware of [37]. A recent study has developed an instrument designed not only to observe, but also map and inform teachers about their technical and social SOT competences in an authentic setting [7], based on the SOT framework of Grammens et al. [10]. This instrument translates each competence outlined in Figure 1 under 'Learning outcomes', into detailed behavioral indicators and three levels of competence development (for an example, see Figure A2). To support teachers in focused observation of SOT in SOL-lab, in the present study, this competence-based instrument was gradually offered and explored so that teachers gradually learned to observe and map teachers' SOT behavior.

3.2.3. Design Principle 2: Providing and Receiving Feedback

The second design principle is rooted in the power of feedback theory [26]. Feedback can be defined as information given by an agent (self, peer, or expert) regarding different aspects of a persons' performance or understanding [26]. Feedback is a vital component of formative assessment, and one of the most powerful influences on improving performance [26,38]. It provides information that allows a learner to confirm, supplement, overwrite, fine-tune, or reorganize knowledge, skills, and perceptions stored in their memory [39]. There are generally three agents or stakeholders who can provide feedback: (1) the learner themselves, (2) the peer, and (3) an instructor, trainer, or expert. To promote the development of teachers' SOT competences, it is crucial that the teachers in our PD

program engage in activities that stimulate providing and receiving feedback with all three stakeholders [26].

The first agent is the learner, which in the context of our PD program refers to the teachers themselves. Reviewing one's own lessons is an ideal method for engaging in authentic self-reflection [40]. Furthermore, it provides opportunities to zoom in on a specific aspect of your own teaching practice and reflect upon it. Research indicates that the quality of teachers' self-reflection improved after they observed recordings of their own teaching practices [41].

The second agent is a peer, which in our case refers to a teacher's colleague. Teachers indicate that they learn a lot from each other [42]. Peer feedback is valuable for both the provider and the receiver of the feedback [43], especially when feedback is delivered using well-designed criteria. Prior research revealed that feedback has a significant impact on teachers' professional competences [44,45], including teachers' self-efficacy [46]. Unfortunately, opportunities for in-service online teachers to observe each other and provide targeted feedback in their daily practice are often limited.

The third agent that can provide feedback is an expert. Expert feedback is often highly valued, as experts possess a more comprehensive knowledge base, and their observations and feedback can be more targeted towards specific competences within the complexity of an online lesson, compared to novices [46].

Online PD offers the possibility of simultaneously combining feedback from these three agents, independent of location and time [32,47]. This capability is a strength that we aimed to leverage to its fullest extent in our PD program. The time- and location-independent nature of video-based online PD programs is particularly advantageous, especially for experts, as they cannot be physically omnipresent [46].

While feedback holds significant influence, its effectiveness can vary according to the content or style. Hattie and Timperley [26] state that effective feedback must answer three major feedback questions: "What are the goals?" (i.e., feed up), "What progress is being made towards the goals?" (i.e., feed back), and "What activities need to be undertaken to make better progress?" (i.e., feed forward). An optimal learning environment or experience is achieved when both teachers and students actively pursue answers to each of these questions [48]. Other researchers articulate it differently, but substantively, it amounts to the same. According to them, effective feedback contains two types of information: verification and elaboration [49,50]. 'Verification' is seen as a judgment to indicate if the behavior is right or wrong, and 'elaboration' contains the information to help the person with error correction [51]. If we use the distinction made by Van Den Berg et al. [52] and compare it to the idea of Hattie and Timperley [26], it could be said that feedback could be informative (providing verification and elaboration) about what has been done or about previous performance (feed back), but also suggestive about what should be done or on how future performance can be improved (feed forward) [48,53]. The effectiveness of feedback can also vary, according to the focus of the feedback [48]. Providing structured feedback that is very specific, both positive and negative, increases teachers' learning [53] and enhances teachers' performance [54]. Further, it is important for teachers to understand, and particularly, to internalize the learning objectives, as it is a crucial prerequisite for delivering and receiving effective feedback [55,56]. In our PD program we translated the theoretical groundings according to the content and focus of feedback, and we aimed to gradually instruct the teachers to provide feedback. Therefore, the teachers were offered a pre-structured template, which incorporates both a competence-based instrument that is linked to the learning objectives of the PD program and two specific questions. These questions aimed to encourage teachers to encompass both informative (feedback) and suggestive (feed forward) information in the feedback exercises. This instruction activity aligns with research suggesting that using well-designed tools enhances feedback effectiveness [57,58].

3.2.4. Design Principle 3: Stimulating the Transfer of Learning

The third design principle is linked to the transfer of learning [27]. In teacher PD programs, transfer of learning is a central consideration in the design of learning activities. The aim is to ensure the effective transfer of acquired knowledge and skills into teaching practices, with the goal of creating sustainable interventions [59,60]. Despite the challenges inherent in promoting transfer of learning in professional settings, insights from research can inform the design and implementation of more effective PD programs that enhance individuals' abilities to transfer learning to their job tasks and responsibilities, ultimately contributing to improved performance. Research in this field has highlighted the complex interplay of factors influencing transfer of learning [60]. They can be classified into three domains, which are individual learner characteristics, the design characteristics of the PD program, and the work environment [59].

First, regarding the individual learner characteristics, the ability, personality, and motivation of the teacher are crucial attributes for facilitating the transfer of learning [60]. For instance, teachers' pretraining motivation may serve as a predictor for the actual training outcome [61]. Accordingly, we have chosen to offer participants the autonomy to decide their involvement in the PD program, as it was not compulsory within their organization.

Second, regarding the design characteristics of the PD program, research emphasizes the importance of content relevance and aligning a variety of online PD activities as closely as possible with authentic teaching content [62]. In our PD program, we focused extensively on using videos of authentic lesson recordings. It is essential for teachers to perceive a strong relationship between the PD content and the demands of their teaching role to effectively transfer their skills to the workplace [27,61]. Burke and Hutchins [61] furthermore, showed that teachers who perceived the PD program as relevant demonstrated higher levels of immediate skill transfer [61]. Equally important is providing opportunities for practice and feedback, as cognitive or mental rehearsal and behavioral modelling during PD have a positive impact on the transfer of learning [61,63]. Teachers must transfer the newly acquired competences from the PD activities to novel teaching contexts, thereby applying the new knowledge and skills to their prior knowledge [59]. In this light, Botma and colleagues [64] developed a conceptual framework to design PD that promotes transfer of learning, consisting of four steps: (1) activation of existing knowledge (e.g., identifying teachers' prior experience), (2) engagement with new information (e.g., allowing teachers to actively connect and experiment with the new content through various activities), (3) demonstration of competence (e.g., involving teachers in practices aimed to improve their performance), and (4) application to real-world practice (e.g., creating a conducive learning climate in the workplace). To stimulate the transfer of learning, regarding the design characteristics of the PD program, various effective teaching and learning activities were combined and incorporated into the present PD program [62,64,65]. First, to support teachers in identifying their prior experience according to their SOT competences, various activities were offered, so that teachers could activate their existing knowledge. Second, to allow teachers to experiment with new content, they could actively interact with expert videos and good practices of colleagues. Third, to engage teachers in practice, we allowed them to demonstrate newly acquired competences. Finally, to create a conducive learning climate in the workplace, teachers had the opportunity to integrate their newly acquired SOT competences into their authentic teaching practice.

Finally, regarding the work environment, both support with, and opportunities to apply, the newly acquired skills that teachers are trained in serve as influential factors for the transfer of learning and training [59,61]. For instance, peer support, such as peer observation, has been demonstrated to have a positive impact on teachers' competences and practices, as well as facilitating the transfer of results from teacher PD programs. Additionally, the opportunity to apply newly acquired skills to their teaching practice is conducive for teachers' transfer of learning [63,66]. Accordingly, we have chosen to make the program as hands-on as possible. Furthermore, participants in our PD program were

all active teachers, who were able to use and apply the newly acquired skills right away in their own practice.

Considering those three domains of influencing factors, Vermeulen and Admiraal [67] advocate for a more thorough examination of the process of transfer, focusing on the ongoing exchange between the PD program and the authentic context. They stress the value of integrating activities within the PD program that focus on incorporating learned content into an authentic classroom practice, while also considering the motivation and self-efficacy of the learner (how and what the teacher aims to integrate into their classroom practice). Moreover, they advocate for ongoing learning opportunities in the workplace, even after the PD program, to enable teachers to refine their competences. They argue that transfer is a two-way or recurring process, where the continuous interchange between the PD program and work contexts is crucial. Drawing on the insights from Vermeulen and Admiraal [67], our aim is to provide continuous learning opportunities that extend the initial PD program, fostering an ongoing exchange between the training provided and the authentic work context. Furthermore, we will ensure that SOL-lab remains accessible even after its formal conclusion, allowing for sustained teacher development and adaptation to emerging educational challenges.

3.3. *Micro-Level Description of SOL-Lab*

Finally, the fourth component of the framework proposed by Bouwer and De Smedt [19] focusses on the micro-level description of the instructional activities, learning activities, and instructional materials that are central in the intervention. In what follows, we will detail the design of SOL-lab, the intervention study. This design adheres to the macro-level design principles previously outlined and aligns with the nine key features of designing a PD program as delineated by Merchie and colleagues [13], as well as the design challenges for online PD [16].

3.3.1. A Comprehensive Overview of the Online PD Program: Navigating Through SOL-Lab

SOL-lab is an online PD program in which teachers were guided through seven modules, with a focus on (re)creating one of their own lessons. The program was conducted from September till November 2023, spanning eight weeks, with one module launched per week. The online content was progressively unlocked, and diverse learning opportunities were offered to enhance teachers' SOT technical and social competences. Teachers were allocated one week to complete each module, with the exception of two weeks for Module 6—Microteaching. Within the week, the participating teachers were flexible regarding the pace and moments in time, given that all modules (except for Module 2 and Module 6) were organized asynchronously. An overview of the program can be found in Table 2. The entire PD program was conducted in Dutch.

Module 1 introduces teachers to SOL-lab and offers detailed information about the content, structure, timeline, and objectives of the PD program. Additionally, the module outlines the overarching assignment for the program and introduces the PD diary which each teacher will use to reflect regularly on the learning activities in the program, their own learning goals, their teaching practice, and how they can integrate the content offered into their own classroom practice. Lastly, teachers are asked to observe one of their own lessons and self-reflect on it, using a competence-based rubric, to map their technical and social SOT competences at the start of the PD program. It is important for teachers that the online PD program is well-structured and has clear objectives [16].

In Module 2, teachers participate in a synchronous online kickoff session where they meet peers enrolled in the PD program, exchange concrete ideas to inspire one another, and outline their learning objectives for the program. Engaging in an online environment as a participant to a PD activity can be beneficial in view of teachers' own teaching practices in online environments, as so far, most teachers are trained in a more traditional, physical face-to-face environments which are not necessarily rich in technology. Throughout this

module, the social role of the synchronous online teacher was modeled by the first author of this article, who led the kickoff session, aiming for constructive alignment in what we want teachers to know, do, and be [68].

Table 2. An overview of the modules of SOL-lab.

Module	Title	Teachers' Activities and Content of the Module
Module 1	Nice to meet you!	Teachers being introduced to SOL-lab (i.e., objectives, content, and timeline), the overall assignment and PD diary; and need to self-reflect on a lesson
Module 2	Starting together	Teachers participating in a synchronous online kickoff session that is focused on meeting peers and inspiring each other (i.e., modelling)
Module 3	The technical role	Teachers acquiring technical SOT competences through instructional videos, knowledge exchange, observations, and feedback tasks
Module 4	The social role	Teachers acquiring social SOT competences through instructional videos, knowledge exchange, observations, and feedback tasks
Module 5	(Re)Designing your own lesson	Teachers putting the theory into practice and redesigning their own introductory lesson, with support of their own reflections in their PD diary
Module 6	Microteaching	Teachers implementing their redesigned introductory lesson by teaching it to a colleague, followed by self-, peer, and expert feedback
Module 7	Wrap up	Teachers filling in a questionnaire, followed by a personal interview to share their experience and progress

In Module 3, the emphasis is on the technical aspects of the synchronous online teacher, while Module 4 shifts the focus to the social aspects. Both modules follow a similar gradual format, where various competences are practiced incrementally through instructional videos, knowledge and experience exchange, targeted observation of good practices, and, ultimately, providing and receiving feedback to oneself and peers (for examples, see Figure A1). This process is facilitated by a competence-based observation instrument (see Figure A2), which teachers had to gradually learn to apply to self-reflect or provide peer feedback, initially on small segments of lessons, and eventually on an entire lesson. All learning activities are aimed at acquiring the necessary technical and social competences of a synchronous online teacher.

In Module 5, teachers are introduced to the overarching assignment. This module empowers them to (re)design their own introductory lesson, which is the first lesson they give to new students. They are encouraged to incorporate all the knowledge and experiences gained from the preceding modules into this lesson. Therefore, they are encouraged to look back at the reflections in their PD diary regarding how they intended to apply the theory into their teaching practice.

Module 6 involves teachers in delivering their (re)designed introductory lesson to each other in pairs, a process known as microteaching. Following the delivery, they are required to engage in self-reflection by providing self-feedback on their own lesson. Subsequently, they are tasked with providing peer feedback on the introductory lesson that was given by the peer, and where they participated in by playing the student role. In this way, teachers can share their experiences, which is important in the design of an online PD, and receive feedback from their peer, too [16]. Additionally, they receive expert feedback on their (re)designed lesson.

Module 7 concludes the PD program with a questionnaire and personalized interviews with each teacher to assess their experiences and progress.

3.3.2. Operationalization of the First Design Principle, “Focused Observation of SOT” in SOL-Lab

An overview of the instructional and learning activities, related to the design principle of focused observation of SOT lessons can be found in Table 3.

To enhance teachers' SOT competences, it is crucial for them to first acquire a comprehensive understanding of the necessary knowledge, skills, and attitudes. Following this understanding, teachers can engage in focused observation and learning. To facilitate

this process, a competence-based observation instrument was introduced. This instrument consists of eleven rubrics covering all relevant aspects of technical and social competences in SOT. Each rubric covers one competence and comprises a list of specific behavioral indicators and three levels of descriptions of competence development for that specific competence (see Figure A2), recognizing that teachers have the capacity to advance and refine their skills in SOT [11,69]. Throughout the PD program, the teachers gradually learned to engage in targeted observation, using the instrument. Initially, they focused on small segments of lessons, concentrating on specific competences. Eventually teachers applied the instrument to entire online lessons, assessing the full range of technical and social competences.

As teachers progress in the PD program, they transition into actively applying and refining their technical and social SOT competences through observation and reflection. This transition involves leveraging both peer and self-observation to deepen their understanding and improve their practice. Consequently, teaching and learning activities that involve both peer and self-observation are encouraged within the SOL-lab environment, triggering teachers' cognitive activation and keeping them focused [16].

Peer observation in SOL-lab. Teachers acquire significant learning experiences in SOT by observing colleagues [1,6,25,29]. Hence, good practices from peers were thoughtfully selected for integration into Module 3 (focusing on the technical role) and Module 4 (focusing on the social role) of the PD program. The lesson fragments were carefully selected and aligned with specific competences. One specific competence was focused upon in each of the lesson fragments. This approach helps in addressing the common issue of data overload in video-based PD by structuring the authentic content in such a way that it allows teachers to concentrate on one central SOT competence at a time [30].

Furthermore, we aim to fulfill Bandura's four conditions for observational learning [34]. (1) To encourage focused attention, concrete behavioral indicators related to the specific competence addressed in the exercises were provided, alongside each lesson excerpt for teachers to consider. Additionally, teachers were asked to indicate the level of competence development they perceived for each skill. (2) To enhance retention, after each observation, teachers were required to engage in an activity in their PD diary that promotes reflection (see Figure A3, for an example of such a reflection exercise). (3) Regarding reproduction, teachers were tasked with revising their lesson based on their observations and delivering the redesigned lesson to a peer in modules 5 and 6. Finally, (4) motivation also influences observational learning [34]. Therefore, a varied range of good practices was offered, allowing teachers to select practices based on educational level or interest (e.g., for technical tools) (see Figure A1). As teachers compared observed teaching behavior with their own teaching practices [35], it is essential to align as closely as possible with each teacher's specific instructional context.

Self-observation in SOL-lab. At the beginning of the PD program in Module 1, teachers were assigned the task of observing their own lesson. This activity aimed to help them gain a comprehensive understanding of their SOT competences as they embarked on their PD journey, while at the same time providing them with an activating experience in terms of immersion, authenticity, and motivation [70]. Using the competence-based instrument developed by Grammens and De Wever [7], this activity enabled individuals to deliberately observe themselves from various perspectives, potentially identifying aspects of their teaching methods they were not consciously aware of [37] and mapping their own level of competence development levels.

Table 3. Operationalization of the design principle focused observation of SOT in SOL-lab.

Macro-Level Design Principle of SOL-Lab	Micro-Level Description of SOL-Lab
Design Principle 1: Focused Observation of SOT Lessons	Instructional Activities • The PD program explains the structure and content of the competence-based observation instrument PEER OBSERVATION IN SOL-lab • The PD program provides opportunities to learn to observe SOT practices of peers with the competence-based instrument (peer observation) - o Encouraging focused attention ■ Providing concrete behavioral indicators according to the specific competency addressed in the video - o Stimulating retention ■ Providing a PD diary to stimulate reflection - o Ensuring reproduction ■ Supporting teachers to (re)design their lesson according to (their reflection of) the observed videos - o Motivating ■ Offering multiple good practices which teachers can choose from (according to educational level or interest) SELF-OBSERVATION IN SOL-lab • The PD program provides opportunities to learn to observe SOT practices of themselves with the competence-based instrument (self-observation) - o Supporting teachers to select, upload and observe a video of their own teaching practice, according to a particular competence • The PD program supports teachers in observing an entire online lesson of themselves with the competence-based instrument Learning Activities • Exploring the competence-based observation instrument PEER OBSERVATION IN SOL-lab • Gradually improving how to observe with the competence-based instrument, both in peer observation and self-observation. - o Peer observation ■ Choosing lesson segments based on educational level or interest ■ Observing lesson segments focused on a specific SOT competence and reflecting on it ■ Observing an entire online lesson for the full range of SOT competences SELF-OBSERVATION IN SOL-lab - o Self-observation ■ Selecting and observing lesson segments focused on a specific SOT competence and reflecting on the value of it in the PD diary ■ Observing an entire online lesson for the full range of SOT competences

Teachers learn how to teach synchronously online by observing others (peer-observation) and seeing themselves in action and reflecting on it [1,6,25,29,36,70] with the aid of a competence-based instrument [7]. The four conditions for observational learning were integrated into the PD program [25].

At the end of Modules 3 and 4, teachers were prompted to review recordings of their own lessons and reflect on them. Subsequently, they were instructed to select and upload a lesson excerpt they had observed, either one which they were proud of and wished to share with a colleague and an expert (the main researcher who led the intervention), or a lesson where they encountered difficulties and wanted to receive feedback from a colleague or expert. Additionally, the teachers were asked to indicate in their PD diary how they valued self-observing their lesson and to provide a rationale for their valuation (see Figure A3). The integration of own lesson fragments is intentionally reserved for the module's conclusion, following the observation of good practices by peers who encounter similar challenges in online teaching. This approach, first observing others and then themselves, aims to boost teachers' confidence in sharing their lesson records with colleagues [33].

In the overarching assessment for the PD program (Module 5), participants were also instructed to critically evaluate the content and structure of their previous introductory lesson before redesigning their new introductory lesson. After presenting their revised introductory lesson to a colleague, they were required to observe themselves for the last time in this PD program.

3.3.3. Operationalization of the Second Design Principle, DP2, "Providing and Receiving Feedback" in SOL-Lab

An overview of the instructional and learning activities, related to the design principle of "providing and receiving feedback" can be found in Table 4.

Gradually learning to formulate feedback. Providing and receiving feedback is an effective method for supporting teachers' performance [47,48]. In the PD program, feedback was facilitated through a pre-structured template that incorporates the competence-based instrument and specific questions. This approach is in line with research suggesting that feedback's effectiveness is heightened when complemented by well-designed tools like structured feedback forms or rubrics [57,58].

As discussed in 'focused observation of SOT lessons', teachers initially learn to observe using the competence-based instrument, previously developed by Grammens and De Wever [7]. This instrument elaborates on each competence listed in Figure 1 within the 'Learning Outcomes' section, breaking them down into specific behavioral indicators and three levels of competence development (for an example, see Figure A2). By offering this transparency, the instrument fosters clarity regarding synchronous online teachers' performance, thereby facilitating the feedback process [58]. Consequently, the behavioral indicators and levels of competence development serve as a common language for discussing teachers' technical and social competences in SOT when providing feedback.

Following the observation of selected lesson fragments in the PD program, teachers were required to first assess the level of each specific competence and then provide feedback. Effective feedback should encompass both informative (feedback) and suggestive (feed forward) content [26,52]. To ensure effectiveness, teachers were prompted to address two pre-structured questions after assigning a level to a particular competency: "Why is this (not) going well? Why did you choose this level for this particular competency?" (feedback) and "What improvements could the teacher make in the future regarding this specific competency (feed forward)?" Specificity is paramount for effective feedback [53], so individuals were encouraged to consult the behavioral indicators for inspiration when formulating concrete suggestions. Additionally, they were prompted to develop their own suggestions for improvement.

Table 4. Operationalization of the design principle providing and receiving feedback in SOL-lab.

Macro-Level Design Principle of SOL-Lab	Micro-Level Description of SOL-Lab	
Design Principle 2: Providing and Receiving Feedback	Instructional Activities	Learning Activities
Teachers engage in feedback activities to enhance their SOT performance [47,48]. The provided and received feedback needs to be informative and suggestive, to be effective [26,52].	GRADUALLY LEARNING TO FORMULATE FEEDBACK - The PD program offers a systematic structure to support teachers to provide self- and peer feedback: - Supporting teachers first to assign a competence level to a particular competence - Offering teachers two questions: - Why is this (not) going well? Why did you choose this level for this particular competency?" (feedback) - How could the teacher improve in the future regarding this specific competency (feed forward)?" - Hint to teachers to take a good look at the behavioral indicators to make the FB as specific as possible ENGAGING IN VARIOUS FEEDBACK EXERCISES - The PD program offers different opportunities to learn to provide feedback on SOT practices with the competence-based instrument: - Good practices - Teachers' own lesson fragment - The (re)designed lesson of a peer - Teachers' own (re)designed lesson - The PD program supports teachers in reflecting about the value of the different feedback sources and exercises through a questionnaire and interview at the end of the PD program.	GRADUALLY LEARNING TO FORMULATE FEEDBACK - Gradually improving how to formulate feedback with the competence-based instrument, both in peer observation and self-observation. - Assigning a competence level for a teacher in an observed lesson fragment - Answering two pre-structured feedback questions ENGAGING IN VARIOUS FEEDBACK EXERCISES - Good practices - Observing the lesson fragment - Submitting feedback - Reading the feedback of the other participants of the PD program on that lesson fragment - Comparing and reflecting on similarities and new ideas - Own lesson fragments - Selecting and observing a lesson fragment - Formulating and submitting self-feedback - Reading the received feedback from a peer - Comparing and reflecting on similarities and new ideas - The (re)designed lesson of a peer - Submitting peer feedback - Own redesigned lesson - Submitting self-feedback - Reading the received feedback from a peer and the expert - Reflecting on the value of all three feedback sources for enhancing their SOT competences

Engaging in various feedback exercises. In the PD program, providing and receiving feedback were fundamental aspects integrated across different modules. Initially, teachers were assigned the task of offering feedback on a good practice within the PD program. Subsequently, after submitting their own feedback, teachers had the opportunity to review feedback provided by their peers on the same lesson fragment. In a second phase, teachers were required to choose and evaluate a lesson fragment of their own, focusing first on a technical competence (Module 3) and then on a social competence (Module 4). Initially, teachers were prompted to generate self-feedback, followed by receiving peer feedback from a colleague. By actively prompting teachers to compare their feedback with those of their colleagues and to consider whether the feedback aligns with their own suggestions or introduces new perspectives or ideas, teachers obtain information that enables them to confirm, revise, refine, or restructure their competences [16,39].

Furthermore, in Module 6, teachers were tasked with self-assessing their entire re-designed introductory lesson, evaluating all technical and social SOT competences. This self-assessment was followed by peer feedback from a colleague and expert feedback. Online PD uniquely offers the opportunity to combine feedback from these three sources concurrently, irrespective of geographical constraints and time limitations [32,47]. In Module 7, teachers were asked, through a questionnaire and interview, to reflect on the value of feedback received from each stakeholder and identify which feedback contributed most significantly to enhancing their SOT competences.

3.3.4. Operationalization of the Third Design Principle, DP3, “Stimulating the Transfer of Learning” in SOL-Lab

To facilitate the transfer of newly acquired technical and social SOT competences into practice, a variety of strategies were implemented within SOL-lab [65]. Table 5 provides an overview of the instructional and learning activities related to stimulating the transfer of learning.

Learner characteristics. Considering individual learner characteristics, all teachers participated in the SOL-lab voluntarily. Since participation in the PD program is optional rather than mandatory, teachers typically exhibit high pre-training motivation, which enhances the likelihood of achieving greater transfer outcomes [60,61]. Regarding the work environment, the PD program spanned eight weeks, during which teachers continued to conduct online classes in their authentic contexts. The alignment between the PD program and their daily teaching practice, coupled with the active encouragement of exchange between both contexts, facilitates teachers’ transfer of learning [61,63].

PD design and work environment. Regarding the PD design, different strategies were used to foster the transfer of learning. Firstly, the PD program utilized authentic lesson recordings from the online school to showcase good practices of peers, aligning PD activities closely with the authentic teaching context [27,61,62].

Secondly, teachers maintained a PD diary (for examples, see Figure A3) throughout the program, providing feedback and reflecting on how they would apply newly acquired competences to their own teaching context, leveraging the positive impact of mental behavioral modeling on the transfer of learning [61,63].

Table 5. Operationalization of the design principle stimulating the transfer of learning in SOL-lab.

Macro-Level Design Principle of SOL-Lab	Micro-Level Description Of SOL-Lab	Learning Activities
Design Principle 3: Stimulating the Transfer of Learning	Instructional Activities LEARNER CHARACTERISTICS - The PD program uses transfer strategies with regard to individual learner characteristics - Voluntarily offering the PD program: participants were free to choose whether or not they joined the program PD DESIGN AND WORK ENVIRONMENT - The PD program uses transfer strategies with regard to the design of the PD and the work environment - Providing lesson recordings of authentic SOT lessons - Providing several (reflection) activities in teachers' PD diary - Providing activities that aim to apply teachers' newly acquired competences to their teaching practice: - Stimulating the activation of existing knowledge through different activities (e.g., exchanging tips and inspiration, providing a quiz, setting up a group discussion) - Stimulating engagement with new information (through observational and FB activities) - Asking to demonstrate the newly acquired SOT competences into a microteaching assignment - Actively encouraging the exchange between the PD program and teachers' daily teaching practice - Offering opportunities to apply the newly acquired competences into teachers' daily SOT practice and vice versa, and actively encouraging this	LEARNER CHARACTERISTICS - Voluntarily joining the program PD DESIGN AND WORK ENVIRONMENT - Actively interacting with authentic lesson recordings, from assigning a competence level to providing feedback and feedforward on SOT teaching practices - Reflecting on implementation plans regarding the content of expert videos and good practices of colleagues in the PD diary - Selecting lesson fragments of daily teaching practices to observe and provide feedback on in the PD program - Microteaching: (re)designing an introductory lesson and performing the lesson to a colleague - Applying the newly acquired competences into the daily teaching practice

A range of strategies are integrated into the PD program to enhance the transfer of the newly acquired technical and social SOT competences into teachers' practice [65].

Finally, the structure of the technical and social modules followed the conceptual framework of Botma and colleagues [64], aiming to stimulate the transfer of learning in four steps. First, to activate teachers' existing knowledge, teachers had to exchange tips and inspiration, discuss, and conduct a quiz regarding a specific SOT competence by the start of the module on the technical role (Module 3) and the social role (Module 4) (for examples, see Figure A1). Second, to stimulate the engagement with new information, teachers had to watch instructional videos of experts and good practices of colleagues and reflect on implementation plans regarding the content of the videos (see Figure A3). Hereby it is important to pay attention to the motivation and self-efficacy of the teachers and to let them decide what input from those observed practices they want to integrate into their teaching practice, and how they want to do it [62,67]. Furthermore, teachers had to actively interact with those videos, from assigning a competence level to providing feedback and feedforward. In this way teachers actively connect with the (new) competences through various activities. Third, to enhance the demonstration of competences, at the end of the PD program, teachers had to demonstrate their newly acquired competences and integrate everything they had learned during the former modules and which they had consciously chosen to integrate into their own practice in the (re)design of their own introductory lesson, and teach the lesson to a colleague (i.e., microteaching). This shared learning experience and exchange of ideas is particularly important when designing an online PD program [12,16]. Fourth, regarding the application to real-world practice, the overlapping occurrence of the PD program and daily teaching practice, along with the active encouragement of exchange between both contexts (e.g., by demanding real lesson snippets for peer feedback during PD), is conducive to teachers' transfer of learning [61,63,66]. This also answers the call of Vermeulen and Admiraal [67] to conduct a more comprehensive analysis of the transfer process, whereby transfer is seen as a two-way or recurring process between the PD and the work environments.

3.4. Teachers' Experiences Regarding the Integration of the Nine Key Features of PD into SOL-Lab

To evaluate how teachers experienced the implementation of the nine core features that support effective PD into SOL-lab [13], the results of the questionnaire were analyzed. The descriptive statistics on teachers' perception are presented in Table 6.

Table 6. Teachers' experiences regarding the implementation of the core features that support effective PD [13].

Items	Mean	SD
The PD focused on what teachers' SOT TC and SC entail	8.76	0.44
The PD focused on how to enhance teachers' SOT TC and SC	8.71	0.47
The PD program was coherent and based on theory	8.76	0.44
The PD addressed SOT teachers' needs	8.00	1.12
The PD lasted long enough to be able to put the learning into practice	8.24	0.75
The PD enabled me to get to know my colleagues better	7.71	1.96
The PD focused on the specific context of the company	8.65	0.49
The PD offered ample opportunities to apply the theory into practice	8.47	0.62
The PD was conducted by a trainer with sufficient SOT knowledge and experience	8.82	0.39

Note. items on a 9-point Likert scale, ranging from 1 'disagree' to 9 'fully agree'.

The questionnaire findings indicate that teachers express satisfaction with the integration of the nine core features supporting effective PD within SOL-lab. These results are further corroborated by insights gained from the interviews. First, teachers commend the PD program for its emphasis on clearly defining the specific technical and social competences that are essential for SOT.

'The rubrics were quite handy because they provided clear insights into certain competences and what falls under the realm of technical skills. For example, they emphasized the importance of citing sources when demonstrating healthy and

safe digital behavior. Using these rubrics gives you a better understanding and overview of what the SOT competences entail.'

Second, the teachers specifically appreciated the inclusion of practical applications within the online modules. From observing others demonstrating successful approaches to enhance their SOT competences (i.e., through good practice and expert videos), to (re)designing and teaching a lesson themselves (i.e., through the assignment).

'To me, the most significant benefit of the training was the opportunity to learn new things and immediately put them into practice. I appreciated the chance to practice alongside a colleague rather than having to implement new tools immediately in a lesson. I found that aspect particularly appealing and considered it a standout feature of the training.'

Third, the teachers noted that the online PD program exhibited a high level of coherence and was well rooted in theoretical principles.

'I'm really impressed with the training. I think it's organized incredibly well and professionally. The different components seamlessly build upon each other, which I find very cohesive. Beginning with theory, always complemented with videos or practical materials, adds a lot to the experience.'

Fourth, according to the teachers, the program aligned with their training objectives and needs.

'The training was very relevant to me because, as an online teacher, there isn't specialized training available for our field. While other programs may offer some benefits, I still have to adapt them to suit the online learning environment, which makes this training extremely pertinent. Yes, it truly makes a difference.'

They particularly valued the diverse range of good practices available, allowing them to select the ones that aligned best with their personal interests or closely matched their instructional needs. However, a few teachers who primarily teach adults mentioned that there could be more effective practices tailored to adult education within the selection.

'I came across some enjoyable icebreaker tools during the training. However, I noticed that sometimes the content leaned too much towards younger children. Since my teaching mainly targets individuals aged 16 and above, including adults, I often find that many of these tools aren't quite suitable for my audience.'

Fifth, the majority of teachers agreed that the program afforded them sufficient time to effectively apply their newfound knowledge.

'The modules were structured really nicely, and it was great to be able to go through them at our own pace. Even though there was a time limit, I felt we had enough time to digest the information. I found it practical for everyone that we had each time an entire week to complete tasks, allowing flexibility according to individual convenience.'

Sixth, during the interviews, when we asked the teachers if they gotten to know their colleagues at d-teach better during the program, they expressed varying perspectives on the feeling of togetherness. Some teachers mentioned that they did not feel like they were going through the program together, but also stated that they did not mind this either. They found the synchronous sessions effective for starting together, but preferred proceeding through the online training individually, at their own pace, afterward. Other teachers did feel a sense of togetherness, even during the asynchronous parts of the training. The majority of teachers highlighted their appreciation for being paired with a specific colleague throughout the training, especially for the final assignment (e.g., observing each other's practices and providing feedback). They felt they truly got to know this colleague better and would reach out to them in the future with questions or to collaborate on testing out ideas.

‘I definitely considered the interaction with colleagues as one of the training’s strengths. For instance, during the synchronous session where we had the opportunity to see each other live. However, what I particularly appreciated was being paired with a specific colleague throughout the training. It was incredibly rewarding to observe her approach to things and to engage in sharing experiences, especially during the live try-out lesson where we discussed our teaching practices. I found this aspect of the training to be extremely valuable.’

Seventh, the teachers appreciated that the PD program focused on the specific context of d-teach. They found it valuable that the expert videos and good practices were contextualized within their daily teaching environment.

‘These expert videos, especially the ones on PowerPoint, were fantastic. Watching colleagues in action sparked so many new ideas. It’s like, “Oh, I could try it this way or that.” It didn’t feel like a big leap to incorporate those ideas into my own daily teaching. So, yes, these videos were definitely the highlight for me.’

Eighth, the teachers valued the hands-on approach of the PD program. Teachers actively learned by observing themselves or others, providing and receiving feedback. Additionally, most teachers emphasized that they learned a lot from the process of redesigning and teaching their own introductory lesson.

‘The practical component was definitely a highlight for me, and having it integrated into the training was very motivating. It was really beneficial to dive right into applying the wealth of information we received. I thought it was interesting to start with a try-out lesson that we had already taught and then work through the other modules to see how we could improve it. Having that opportunity right from the start of the course was motivating, encouraging us to test things out right away rather than procrastinate. Working with a colleague on this was also fascinating, and receiving feedback from various people offered another layer of understanding. The interaction and feedback throughout the training were highly beneficial for me.’

Furthermore, throughout the interviews, teachers mentioned that the PD diary provided an extra advantage by fostering continuous reflection on the information being provided.

‘I enjoyed the use of the PD diary. Sometimes, you can read things and think, “Oh, that’s interesting, and that’s interesting too . . .” But in the end, the diary prompts you to reflect again. Like, “Okay, what did I personally find relevant? And how am I going to implement that in my own classroom practice?” Yes, that was insightful.’

Ninth, the teachers shared the opinion that the trainer had sufficient SOT knowledge and experience to provide them with qualitative feedback.

‘The experts’ feedback was particularly helpful in strengthen my SOT competences. It was incredibly targeted and personalized, coming from such expertise. It was the most extensive and comprehensive, including references to specific situations.’

4. Discussion

The first aim of this study was to systematically describe the development of an online PD program that uniquely integrates three promising design principles in the context of SOT, using the framework of Bouwer and De Smedt [19]. By offering a comprehensive and analytical description of SOL-lab, we aim to fill the gap often found in detailed descriptions of PD programs [19]. The design of the PD program was guided by three macro-level design principles: (1) focused observation of SOT, (2) providing and receiving feedback, and (3) stimulating the transfer of learning. Theoretical validity was ensured, as various

theoretical frameworks and empirical foundations related to these principles guided the design process of SOL-lab, including the development of specific instructional and learning activities at the micro level. This study uniquely integrates frameworks of observational learning, particularly the social learning theory, with the power of feedback to stimulate the transfer of learning within the specific design of an online PD program on SOT [10,25–27].

Focused observation of SOT, the first design principle, lays the foundation by emphasizing the importance of teachers observing both their own practices and those of their peers, thereby fostering reflective practice and competence improvement [1,25,36,37,67]. This study is the first to operationalize the theoretical SOT framework of Grammens et al. [10], who identified specific competences required for SOT and developed a competence-based instrument for focused observation of technical and social SOT competences [7]. These self- and peer observations contribute to the second design principle: providing and receiving feedback. Engaging in feedback activities helps teachers enhance their SOT competences and improves their self-awareness [12,17,26]. Finally, stimulating the transfer of learning ensures that the skills acquired through observation and feedback are effectively applied in the SOT context. By integrating authentic learning experiences into the PD program and encouraging active experimentation, this third principle ensures a robust connection between learning and real-world application, facilitating the integration of new competences [18,27,67]. Together, these principles create a synergistic approach to teacher development, promoting continuous growth and effectiveness in SOT. This study responds to the call for increased investments in evidence-based PD initiatives tailored for in-service teachers within the domain of SOT [1,4,6]. Additionally, throughout the development of SOL-lab, we incorporated the nine key features of effective PD programs [13], leading us to the second aim of our study.

The second aim of the study was to assess to what extent teachers experienced the integration of the nine key features, defined by Merchie et al. [13], into the online PD program. Overall, the descriptive results showed that the teachers were highly satisfied with the integration of the nine essential and research-based features supporting effective PD within SOL-lab [13]. This finding has implications for practice, as educators can use the design of SOL-lab to improve their online PD programs for SOT, ensuring they remain relevant and effective in meeting teachers' need. During the development of SOL-lab, we encountered two design challenges, which we will discuss and for which we will provide suggestions in view of the design of future PD programs.

The first design challenge is related to the key feature 'collective or collaborative participation' on which teachers' opinions were the most diverse. The qualitative analysis revealed that teachers expressed varied views on the sense of togetherness. Some teachers did not feel they were progressing through the program collectively, but this did not concern them. They valued the synchronous sessions for starting together but preferred to continue the training individually at their own pace. Conversely, other teachers felt a sense of togetherness, even during asynchronous parts. Most teachers appreciated being paired with a specific colleague for the final assignment and during the previous exercises (e.g., observing each other's practices and providing feedback), which confirms the recommendation of Meyer [16] to create pairs or smaller groups who continue working together throughout the PD program. This helped teachers build stronger professional relationships and facilitated future collaboration. As prior research has shown that peer learning can enhance teachers' confidence [18], and that sharing experiences with colleagues and receiving feedback are important for supporting PD among SOT teachers [6], we recommend that future research provide additional opportunities for peer collaboration in PD programs. Especially in online PD programs, peer collaboration can enhance a sense of belonging and provide opportunities for collaborative professional growth, as observed in our study as well [12,17]. However, it should be noted that not every teacher may feel a need for this. Therefore, we suggest including a weekly online meeting that teachers can join voluntarily to exchange ideas and experiences in future PD programs. Each week, a different topic or help request can be the focus of these meetings.

A second design challenge we experienced while integrating the key feature ‘ownership’ was addressing the diverse needs and interests of SOT teachers, as the target group was highly diverse. We addressed this challenge by offering a selection of good practices from which teachers could choose, based on their personal preferences and needs. Although the qualitative analysis revealed that the content of SOL-lab aligned with their training objectives and needs, a few teachers indicated that there could be more effective practices tailored to adult education within the selection provided, which highlights an area of interest for further studies on PD for SOT.

In sum, the overall design check we conducted is important, because it confirms that the intended quality features integrated into the program were generally perceived as such by the participants, and it also identified some areas for improvement. By evaluating teachers’ experiences according to the implementation of the nine key features, we contribute to the research in this field, as a minority of studies explicitly focus on the evaluation of these features [13].

The present design study offers three main implications for practice and further research. First, the design and implementation of SOL-lab addresses the urgent need for greater investment in evidence-based PD programs specifically tailored to SOT [1,4,6]. Our study provides valuable insights for further developing effective online PD initiatives, and may encourage PD providers to specifically disseminate SOL-lab, as well as to generally invest more in online PD programs on SOT.

Second, while previous studies often lack detailed micro descriptions of the design principles in their PD programs, our study aimed to provide a detailed description of the design principles of SOL-lab. This can support PD providers in implementing these evidence-informed design principles into their programs [17,19–21]. Additionally, the framework developed by Bouwer and De Smedt [19] was successfully applied, demonstrating its potential for use also in other studies that describe and design professional development programs.

Third, our study contributes to theory building and enhances our understanding of how to improve teachers’ technical and social SOT competences [1,6,19]. By explicitly defining and sharing our design process, from the theoretical framework to concrete learning and instructional activities, we aim to set a good example and encourage future research to adopt this approach. Since the specific context of an intervention significantly influences the selection of design principles [13,19], we recommend that future research test the adaptability and scalability of the PD program and its design principles to a broader audience, encompassing diverse educational levels and disciplines, and elucidate on these contextual factors, along with teachers’ characteristics.

5. Conclusions

The design of the PD program SOL-lab is theoretically sound, and teachers experienced the intended effective characteristics of the program. This design study holds significance, as it establishes clear guidelines for future research and PD initiatives aimed at improving teachers’ technical and social SOT competences. The study has the potential to facilitate the implementation, replication, and dissemination of SOL-lab specifically, and to enhance teachers’ technical and social SOT competences more broadly. Further research is necessary to evaluate the impact of SOL-lab on teachers’ technical and social SOT competences.

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Institutional Review Board Statement: The research was conducted according to the ethical rules presented in the General Ethical Protocol of the Faculty of Psychology and Educational Sciences of Ghent University, a formal approval is not needed for this kind of research.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: Maaike Grammens, the first author of this manuscript is affiliated with d-teach, an organization that is specialized in online and blended learning. She holds the position of professional development leader at d-teach, which is divided into two divisions: d-teach online training and d-teach online school. The former operates as an expertise and online training center to support higher education and companies with online and blended learning, while the latter is an international not-for-profit organization that provides online education to students all over the world. The manuscript includes a customized online PD program developed specifically for the online instructors at d-teach online school, who also participated in the PD program.

Appendix A

The screenshot displays the d-teach online training platform. On the left, a sidebar lists the course structure: Week 0: Hallo!, Week 1: Samen van start!, Week 2: De technische rol, Week 3: De sociale rol (selected), Week 4: Try-out les herverken, Week 5-6: Microteaching, and Week 7: Wrap up. The main content area is titled 'Samen van start' and includes a progress bar showing '100% COMPLETE 37/37 Steps'. The text describes the d-teach online school's global reach and encourages users to create a film clip about their own location. Below the text is a world map titled 'd-teachers wereldwijd' showing various countries and cities marked with pins, indicating the global distribution of d-teach teachers.

Figure A1. Cont.

Figure A1. Cont.

Een positieve houding hebben ten aanzien van het gebruik van technologie in het onderwijs

Als online leerkracht bent je 'pro' online leren en leerinnovatie. Je **experimenteert** graag met **nieuwe tools** en staat te popelen om eens een leuke website **uit te testen** met je leerlingen. En ja, soms loopt er technisch eens iets fout. So what? Al doende leer je!

Wat betekent het concreet om een positieve houding te hebben ten aanzien van het gebruik van technologie?

Gedragsindicatoren:

- De leraar straalt vertrouwen uit tijdens het online lesgeven.
- De leraar licht de (meer)waarde van een online activiteit toe die hij introduceert in de les.
- De leraar durft gebruik te maken van nieuwe technologieën tijdens de online les (bv. tools, softwaretoepassingen, innovatieve leertechnologieën, ...).
- De leraar stelt zich positief op wanneer er zich technische problemen voordoen tijdens de online les.

Welke tool wil jij graag in actie zien?

Klik op één van de drie tools en kijk mee hoe een collega deze tool inzet tijdens de online les (meerdere video's bekijken mag natuurlijk ook). Geef vervolgens feedback op het lesfragment dat je bekeken hebt.

+ Quizlet
+ DigiPuzzle
+ Gynzy
+ Prowise

Klik hieronder op tool die je gekozen heb en bekijk ook de feedback van je collega's

Had je dezelfde niveaukeuze? Wat is hun feedback naar de leraar toe? Komt dit overeen met wat jij voorstelde of lees je enkele nieuwe ideeën?

+ Quizlet
+ DigiPuzzle
+ Gynzy
+ Prowise

Wist je dat ...

Wist je dat technologie taalonderwijs enorm kan versterken? Het online leerplatform Nedbox is hier een mooi voorbeeld van! Dit leerplatform is ontwikkeld voor anderstalige volwassenen en oudere OKAN-leerlingen. Ook binnen d-teach wordt hier actief mee gewerkt!

Klik hier om de website te ontdekken! Klik hier om de app te ontdekken waarmee je ook spreekvaardigheden kan oefenen en waarmee anderstaligen dus waar en wanneer ze willen hun Nederlands kunnen oefenen.

Persoonlijk actieplan

Open je persoonlijk actieplan, technische rol in MS Teams en ga naar week 2 – De technische rol. Scroll naar de competentie 'Een positieve houding hebben ten aanzien van het gebruik van technologie in het onderwijs' en noteer welke video's je hebt bekeken en op welke manier jij één of meerdere tools graag eens wil inzetten tijdens jouw eigen (try-out) les?

Figure A1. Examples from Modules 3 and 4 of SOL-lab.

	BEHAVIORAL INDICATORS	DOES APPLY			DOES NOT APPLY
		BEGINNING	DEVELOPING	PROFICIENT	
Building a learner-learner relationship	- The teacher asks learners to introduce themselves. - The teacher makes time and space at the beginning and end of the online lesson for a general chat. - The teacher introduces an icebreaker activity at the start of the online lesson. - The teacher encourages learners to share their real-world experiences during the online class. - The teacher makes time during the lesson for learners to get to know each other better. - The teacher organizes online group activities to ensure all learners become acquainted with one another. - The teacher designs activities that enable learners to share their ideas, opinions, emotions, and feelings. - The teacher creates opportunities for learners to collaborate or interact with one another synchronously online. - The teacher divides learners into breakout rooms to facilitate social connections alongside learning.	The teacher has not yet encouraged the formation of learner-learner relationships	The teacher encourages the formation of learner-learner relationships, but there is still room for improvement.	The teacher encourages the formation of learner-learner relationships in a good and smooth manner.	There is not enough information in the video to assign a level to this competence.



Figure A2. Example of one rubric of the competence-based observation instrument.

BUILDING A LEARNER-LEARNER RELATIONSHIP

Tips to strengthen the relationship between teacher and student(s)

Did you watch Steffi's video on strengthening the relationship between the teacher and the students? (Highlight your answer)

- Yes, I watched the entire video
- Yes, I watched part of the video
- No

Steffi presented 8 tips. Have you already applied any of these tips in your lessons? If so, which one(s)? (Highlight your answer(s))

- Yes, I have already used Tip 1 'Ensure a warm and friendly welcome.'
- Yes, I have already used Tip 2 'Connect with learners' interests and show interest.'
- Yes, I have already used Tip 3 'Use an icebreaker.'
- Yes, I have already used Tip 4 'Pay attention to non-verbal signals.'
- Yes, I have already used Tip 5 'Use visual aids.'
- Yes, I have already used Tip 6 'Use interactive tools and games.'
- Yes, I have already used Tip 7 'Use positive reinforcement.'
- Yes, I have already used Tip 8 'Collaborate online.'
- No, I have not yet used any of the tips in my lessons.

Which (new) tip would you like to apply in your own (trial) lesson, and do you already have a specific idea of how you would implement it?

Figure A3. Cont.

HAVING A POSITIVE ATTITUDE TOWARDS THE USE OF TECHNOLOGY IN EDUCATION

Online tools

Which videos did you watch? (Highlight your answer(s))

- Quizlet
- Digipuzzle
- Gynzy
- Prowise

Which tool (that is new to you) would you like to use during your own (trial) lesson? (Highlight your answer(s))

- Quizlet
- Digipuzzle
- Gynzy
- Prowise

How do you plan to use these tools during your own (trial) lesson?

GETTING STARTED TOGETHER

Observing yourself

How valuable did you find observing yourself? (Highlight your answer)

1 2 3 4 5 6 7 8 9 10
 Not Very
 valuable valuable

Why do you give this score?

Figure A3. Reflection exercises from the PD diary.

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Article

Technology-Enhanced Feedback System Usability in the Context of Self-Regulation Promotion

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Abstract: Numerous studies have explored the integration of technology-enhanced feedback systems in education. However, there is still a need for further investigation into their specific impact on teacher satisfaction, which is essential for effective feedback delivery to students. This study addresses this gap by analyzing teachers' satisfaction with the "Compliments and Comments Tool", a technology-enhanced system developed to provide written feedback to students. Using a quantitative approach, this study examined teachers' perceptions of the tool's usability in the Slovenian education context, involving a diverse group of 3412 primary and secondary school teachers. Data were collected through surveys employing the System Usability Scale (SUS) and Technology Acceptance Model (TAM) for quantitative analysis, complemented by qualitative insights. The results showed high teacher satisfaction, valuing the tool for facilitating feedback and supporting a positive learning environment. These findings suggest that the "Compliments and Comments Tool" is a valuable addition to educational technology, promoting effective teaching and enhancing student engagement. This study emphasizes the critical role of user-centered design and system usability in educational technology, particularly in fostering effective feedback and promoting student self-regulation.

Keywords: system usability; user-centered design; technology-enhanced feedback; importance of feedback; self-regulation promotion

1. Introduction

In recent years, the integration of technology-enhanced feedback systems into education has demonstrated significant potential for improving student learning outcomes [1], with findings suggesting that such technology use positively influences learners' motivation and achievement [2]. These systems, grounded in constructivist and cognitive learning theories, emphasize the importance of timely and personalized feedback in fostering self-regulation and metacognition among students [3]. The development of students' self-regulated learning skills is critically dependent on receiving appropriate feedback during the learning process [4–6], making effective feedback essential for guiding students toward improved learning practices and self-regulation [3,4]. This feedback helps students understand their current performance levels, identify areas for improvement, and recognize their achievements, thereby fostering a growth mindset that views challenges as opportunities rather than setbacks [4]. This process is crucial for helping students make informed decisions about their learning strategies, promoting self-assessment and reflection, and enhancing critical thinking and problem-solving skills [7]—skills essential for lifelong learning and adaptability.

High-information feedback, which includes not only corrective information but also insights into self-regulation aspects, such as monitoring attention, emotions, or motivation during the learning process, has been found to be particularly effective [8]. A recent meta-analysis of 435 studies highlighted that this type of feedback achieved a substantial effect size of $d = 0.99$, underscoring its significant impact [8]. This comprehensive feedback approach enables students to gain a deeper understanding of their learning processes,

fostering a more engaged and proactive approach to education. Thus, emphasizing the quality and type of feedback is critical in educational settings as it significantly influences student growth and learning outcomes.

Providing comprehensive individual feedback to all students remains a time-consuming task for teachers [9]. Advancements in technology have facilitated this process by enabling teachers to regularly document and share feedback digitally [10,11], either after lessons or even through automated [12] and intelligent [13] systems. This digital approach not only streamlines the feedback process [10] but also enhances parental engagement, which is strongly associated with improved academic success for students [14–16]. However, there is a notable gap in the research, particularly regarding teachers' views on the usability of technology-enhanced feedback systems, despite teachers playing a crucial role in the effective implementation of these systems.

Most studies on technology-supported feedback systems have focused on feedback related to specific tasks, emphasizing learning in terms of knowledge acquisition. Therefore, there is a research gap concerning the usability of feedback systems aimed at the holistic growth and self-regulation of individuals. Furthermore, recent studies have increasingly focused on automating feedback using analytics [17,18] or intelligent systems [13]. Nonetheless, there is a lack of research considering the critical role of teachers' perceptions of the adoption and success of these technologies.

This study aimed to fill this gap by investigating the usability and effectiveness of the “Compliments and Comments Tool” developed with this purpose in mind, featuring categories specifically designed to support holistic growth and self-regulation. Implemented within the Slovenian education system, this tool's usability and impact are assessed by examining teachers' satisfaction with it, their perceptions of its usefulness, and the frequency and appropriateness of its use in providing feedback. By addressing these aspects, this study contributes to the ongoing discourse on educational technology, emphasizing the importance of user-centered design and system usability in fostering an environment conducive to effective feedback and self-regulation among students. This focus on teachers' perspectives and the practical use of the system aims to provide valuable insights into the design and implementation of feedback tools that support both teacher satisfaction and students' personal and academic growth.

2. Literature Review

2.1. Technology-Enhanced Feedback and Its Impact on Students' Self-Regulation

The rapid development and ubiquity of technological paradigms have led to an increased focus on integrating digital methods to provide feedback in educational settings [19]. Empirical research has highlighted the pedagogical effectiveness of digital text feedback, noting its superiority over traditional handwritten counterparts [20]. Digital platforms enable timely and efficient delivery of feedback beyond classroom constraints, allowing them to be tailored to learners' specific needs and preferences [18,21]. Additionally, mobile technologies have been shown to facilitate collaborative learning environments, enhancing student interaction and engagement through shared digital platforms [22]. This capability for systematic storage, monitoring, and analysis of digital feedback facilitates the continuous tracking of student knowledge, learning strategies, skills, and behaviors over extended periods. Additionally, technological tools such as progress graphs and frequency analysis make data visualization accessible to students, teachers, and parents, thereby promoting a comprehensive understanding of student progress [23].

Recent research has emphasized the importance of feedback literacy for both teachers [24,25] and students [26,27]. For teachers, effective feedback literacy involves crafting and delivering feedback that is constructive, clear, and timely using digital tools to enhance engagement and learning outcomes [24]. On the other hand, students must develop the ability to interpret and utilize feedback to improve their learning processes [27]. This dual literacy is essential to ensure that feedback is not only received but also understood and acted upon, leading to improved educational outcomes. However, challenges, such as en-

sureing equitable access [28,29] and developing digital literacy skills among teachers [30,31] and students [32] must be addressed.

Research based on dual-coding theory suggests that while students have an intrinsic preference for auditory (oral) feedback, the cognitive processing required for written feedback, whether analog or digital, significantly enhances comprehension and retention [33]. The impact of written feedback is further amplified when combined with Socratic questioning and collaborative discourse, which fosters self-efficacy, self-regulation, and active learning [34]. The principle of immediacy in sharing feedback, rooted in cognitive load theory, is paramount [5,35]. However, critiques have pointed to the potential pitfalls of written feedback and emphasized the need for sustained dialogic engagement to alleviate cognitive overload and promote schema acquisition [36]. Nonetheless, researchers have found that students frequently ask questions to self-reflect on their tasks while reading written feedback, indicating self-regulatory behavior [5,33].

In classroom settings, most feedback is typically directed to the entire class and, as such, often fails to effectively engage individual students [37]. Personalized feedback, which addresses each student's specific needs and developmental stage [38–41], particularly their zone of proximal development [42,43], is more effective in fostering learning and improvement. Perspectives on the primarily feedforward nature of feedback indicate its positive reception by students, as it significantly contributes to the self-regulation of learning [44,45]. Despite the recognized benefits, delivering individualized and valuable feedback remains a significant challenge for educators because of increasing student-to-teacher ratios and diverse academic needs. Constraints such as time and resources further intensify these challenges, making it difficult to consistently provide comprehensive and high-quality feedback [46,47].

Utilizing technology-enhanced feedback systems can significantly reduce teachers' workload by efficiently managing comprehensive student data and implementing a structured feedback categorization system. These systems allow for the simultaneous distribution of feedback to multiple students, making it easier to provide timely and personalized responses. Additionally, the ability to track and analyze feedback over extended periods offers educators a more detailed understanding of classroom dynamics and individual student progress. This comprehensive analysis provides deeper insights into how students are advancing, both academically and in terms of self-regulation.

Research has indicated that feedback from technologically enhanced learning platforms is a critical factor in reducing dropout rates, increasing course completion rates, and improving overall learning outcomes [48]. Central to our approach is the principle of tailoring feedback to meet individual learning needs, which includes a focus on learners' self-regulation. By providing targeted feedback, educators can more effectively support students in developing self-regulatory skills, thereby enhancing their overall learning experiences. This personalized approach ensures that feedback is not only relevant and actionable but also instrumental in fostering a more engaged and proactive approach to learning.

2.2. Overview of Technology-Enhanced Feedback Tools in Education

Feedback tools are essential in education, shaping student engagement, teacher-student interactions, and overall learning outcomes. Technology-enhanced feedback (TEF) systems have been increasingly implemented to improve feedback quality and effectiveness for students [49]. These systems use various technological tools to provide timely, personalized, and interactive feedback, which is crucial for student learning and development. The role of feedback in enhancing educational experiences and professionalizing teaching practices has been well documented. However, traditional feedback systems often fail to meet modern educational needs, prompting a shift towards technology-driven approaches [46]. Technological advancements have led to the development of diverse feedback tools, from traditional face-to-face interactions to advanced online platforms. These tools deliver immediate, specific, and actionable feedback that significantly contributes to the educational

process [4,46]. The integration of technology into education has given rise to several feedback systems that utilize digital platforms to enhance communication between teachers, students, and parents [50]. The global adoption of these systems varies and is influenced by local educational policies, cultural contexts, and technological infrastructure.

TEF systems employ various tools and techniques. Classroom response systems (CRSs) are used in science instruction for technology-enhanced formative assessment (TEFA), applying principles such as question-driven instruction and dialogic discourse [51]. Video feedback screencasts are used to provide individualized feedback that is favorably perceived by students, providing them with better insight into the assessment process [52]. Additionally, video-enhanced mobile observation (VEO) apps are used in teacher education for peer feedback, supporting self-reflection, and inquiry-based learning [53]. These tools support practices such as question-driven instruction and peer feedback, fostering self-reflection and inquiry-based learning. Despite the potential benefits, TEF systems face challenges related to ease of use, perceived usefulness, and broader socioeconomic and cultural factors that shape educational practices. The effective use of these technologies assumes a high level of digital proficiency among educators, which is not uniformly present across factors such as age, gender, education, and educational institution [54]. This digital divide is a significant barrier to the widespread and effective implementation of TEF tools, limiting their accessibility and impact [55,56]. While video feedback has shown positive outcomes, offering a personalized touch and clarifying complex content [57], it requires robust technology and digital skills among educators.

Integrating technology into parent–teacher communication systems has been shown to significantly enhance parental engagement, a critical predictor of student success [58]. Enhanced engagement results from improved trust and communication, facilitated by feedback systems that use technology to connect parents and educators more effectively [59]. The triangular relationship between students, parents, and teachers ensures consistent messages and support across home and school settings, which is crucial for academic and personal development [60,61].

The rapid development of educational technology continues to transform teaching and learning practices. Recent advances in AI-driven feedback systems support student self-regulation and improve educational outcomes [62,63]. However, continuous research is essential to fully explore the impact of these technologies, as their implementation in diverse educational systems can provide deeper insights into their benefits and limitations. Platforms like “Tutoria” illustrate a shift towards personalized, AI-enhanced feedback systems, catering to the specific needs of both students and teachers, further enriching the educational technology landscape [64]. However, concerns regarding the reliability, authenticity, ethical considerations, and emotional intelligence of AI-generated feedback remain prevalent in academic literature [65,66]. National policies and legal frameworks play a crucial role in this domain, often acting as barriers and constraints for the advancement of AI systems within the educational sector in various countries. These innovations highlight the evolving nature of educational technology and present new opportunities for enhancing the feedback process in educational systems worldwide. However, continued research and development are essential to optimize these systems and fully integrate them into educational practices.

2.3. Comparative Insights from Finnish and Slovenian Technology-Enhanced Feedback Tools in Education

A notable example of a technology-enhanced feedback system integrated as a core educational component is found in the Finnish education system. Finnish schools utilize online platforms that enable teachers to provide structured feedback on student learning and behavior [67]. This system supports daily feedback practices and offers instant feedback during lessons, thereby maintaining continuity and immediacy. These practices have been documented for their high efficiency and positive impact on both teacher performance and student learning outcomes [68,69]. The use of predefined feedback options in Finland

streamlines the feedback process, ensuring consistency and reducing subjective bias, although it may increase teacher workload and potentially diminish student responsibility for self-directed learning [70].

The “Compliments and Comments Tool”, whose usability has been evaluated in this research, was developed in Slovenia with insights from the Finnish system, particularly focusing on the benefits of structured feedback and integration features. However, it incorporates an even more detailed structure tailored to the local context, as research shows that teachers experience high levels of work stress due to parental interference in their work [71]. This tool was designed to enhance direct communication between teachers and parents, potentially boosting parental engagement without disrupting daily educational routines. The categories within the tool are aligned with the development of self-regulation skills and competencies required for the 21st century [72]. By refining and adapting these elements from the Finnish system, the Slovenian tool aims to improve feedback delivery efficiency and effectiveness, addressing local educational needs while leveraging global best practices. The enhancement of the Slovenian system allows for the holistic monitoring of students’ growth and development, focusing on self-regulation skills.

In the context of Slovenian primary and secondary schools, both teachers and students generally lack advanced digital competencies [73], and there are no established systems for comprehensive student monitoring. Consequently, it is crucial that technological developments are tailored to the existing skills and knowledge levels of both students and teachers. The “Compliments and Comments Tool” has been developed to include text-based feedback options, with the potential for audio and video feedback to be incorporated in the future once the necessary resources and skills are available among users and schools. This tool also provides analytics for both teachers and school administrators, offering insights at the class or school level. However, new AI technologies have not been integrated, as their inclusion requires changes in established legal frameworks.

2.4. Feedback System Usability and User-Centred Design

Usability, defined as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” [74], is crucial in technology adoption. User acceptance is influenced by internal beliefs, attitudes, system design, and user involvement [75,76]. Perceived usefulness and ease of use are fundamental to positive attitudes and behavioral intention to use technology [77,78].

Various measures have been employed to assess usability, including the Software Usability Scale (SUS) [79], Software Usability Measurement Inventory (SUMI) [80], User Experience Questionnaire (UEQ) [81], and Technology Acceptance Model (TAM) [75,82]. Brooke created the System Usability Scale (SUS) to assess perceived usability [79]. The SUS is a free psychometric tool that has gained worldwide acceptance due to its high validity and reliability and is, according to Tullis and Albert, the most widely adopted tool for usability evaluations [83].

Blažica and Lewis presented a Slovenian translation, and the results indicated that the SUS-SI has properties similar to the English version and can therefore be used with confidence when conducting user research [82]. Lewis points out that usability can only be defined by reference to specific contexts and not as an absolute concept [84]. The SUS scale is technology-agnostic [85–87] and can therefore be deployed to evaluate various technological products, including school information systems and learning management systems.

Another usability scale widely adopted in educational technology is the Technology Acceptance Model (TAM) [88]. TAM is a holistic approach that combines several aspects of the technology adoption process by considering the characteristics of the user, system, environment, tasks, and context [89]. External variables (i.e., technology characteristics) of the TAM influence both perceived ease of use and usefulness. Perceived ease of use plays a crucial role in TAM because it directly and indirectly influences intention, affecting the

likelihood of using technology [77]. Perceived usefulness is defined as “the degree to which a person believes that using a certain system enhances his or her productivity” [90]. It is significantly influenced by perceived ease of use because the easier a technology is to use, the more useful it becomes. Higher acceptance rates for a product increase the likelihood that it will be used continuously in the future [91].

User-centered system design (UCSD) emphasizes usability throughout the system lifecycle, involving activities such as vision, planning, requirements analysis, prototyping, deployment, and evaluation (Figure 1) [92].

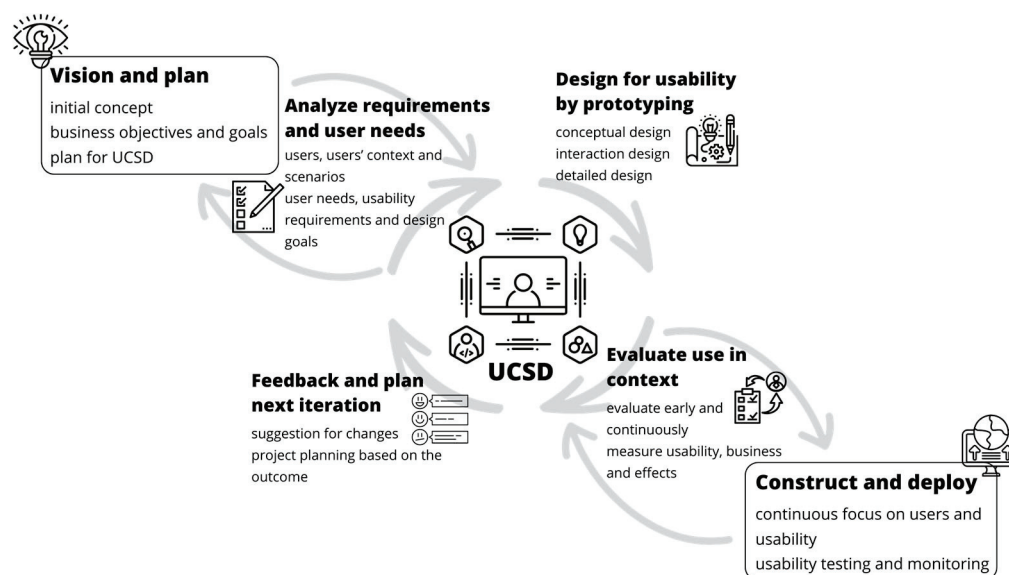


Figure 1. User-centered system design (UCSD) phases.

Continuous iterations and user evaluations are key to enhancing utility and usability [93]. Involving users in the design process increases the likelihood of adoption [76]. Therefore, we included teachers as end users when developing the “Compliments and Comments Tool”.

2.5. Research Questions

Feedback has an impact when given in a timely manner and worded in a way that the learner understands. Parents, especially those of younger students, also play an important role in understanding and responding to the teacher’s feedback.

The usability and user-centered design questionnaire used to analyze user satisfaction with the functionality of the existing “Compliments and Comments Tool” in our case study provides three main areas for measuring user satisfaction:

1. Efficiency, as reflected in the user’s ability to perform the task and the quality of the task itself or its outcome;
2. Ease of use, reflected in the amount of resources used to perform the task;
3. Ease of learning and satisfaction, reflected in the speed and ease of learning to work with the tool and the user’s perceived satisfaction in using the tool.

This research aims to examine teachers’ opinions on the importance and frequency of feedback and assess their satisfaction with the usability of the written feedback tool. The following research questions (RQs) and hypotheses (Hs) were proposed:

RQ1. What are the teachers’ opinions on the importance and frequency of feedback?

Constructivist and cognitive learning theories emphasize the role of frequent personalized feedback in student learning. The objective of RQ1 was to understand the perceived significance and optimal recurrence of feedback as perceived by teachers, influencing their daily interactions and feedback approaches with students and parents.

H1. *There are no gender or age group differences in teachers' opinions on the importance and frequency of feedback given to students and sent to parents.*

This hypothesis aimed to investigate the potential impact of demographic variables on teachers' perceptions of the significance and regularity of feedback.

RQ2. How satisfied are teachers with the usability of written feedback tools?

The objective of RQ2 is to assess the degree of satisfaction among teachers regarding the feedback tool, to identify areas for enhancement, and to comprehend its effectiveness within the educational environment.

H2. *Younger teachers tend to have more experience using technology, while older teachers tend to have more experience in giving feedback. Therefore, age may affect teacher satisfaction with system use, suggesting possible age differences.*

The objective of H2 was to examine how demographic elements, specifically age, influence teachers' satisfaction with the usability of the feedback tool. This goal strives to discern the extent to which varying degrees of technological familiarity and proficiency among younger and older educators affect their assessment of the tool's efficacy and user-friendliness.

H3. *The perceived usefulness of the "Compliments and Comments Tool" for promoting self-regulation and learning strategies will differ between primary and secondary school teachers, with variations in evaluations depending on the educational level at which the teacher works.*

This hypothesis explores whether there are differences in teachers' assessments of the effectiveness of the feedback tool based on the educational level they teach (primary versus secondary). It posits that the tool's impact on self-regulation and learning strategies may be perceived differently because of distinct developmental and educational needs at these levels.

3. Materials and Methods

3.1. Research Design

This study employed a mixed-methods approach, combining both quantitative and qualitative methods, to analyze teachers' opinions on the importance and frequency of feedback and to offer comprehensive insight into teachers' perceived usability of the TEF system "Compliments and Comments Tool". This was developed to help teachers provide feedback easily and efficiently using technology and is seamlessly integrated within the school management information system "e-Asistent" used in Slovenian schools. This research aimed to gather teachers' perceptions of the tool, focusing on its impact on promoting self-regulation and learning strategies among students. Two separate datasets were collected using questionnaires distributed through the "e-Asistent" information system, commonly used in Slovenian schools.

3.2. Participants and Procedure

The participants comprised two distinct groups of teachers. The first dataset was obtained from 106 teachers from a small number of schools involved in the research and development process of "e-Asistent". Schools were purposefully selected from various regions to capture the diverse educational contexts. This sample included 78 women and 15 men, with the majority (61 teachers) aged between 41 and 60 years, followed by 30 teachers aged between 25 and 40 years, and one teacher over 61 years. This purposive sampling approach aims to provide insights from a diverse range of educational settings and perspectives.

The second dataset included responses from 3412 primary and secondary school teachers, representing approximately 13% of all teachers in Slovenia. This broader survey

targeted all schools using the “e-Asistent” system, allowing teachers to participate. The respondents included 2396 women, 573 men, and 443 who did not identify their gender. Additionally, 1063 were secondary school teachers. In the Slovenian educational system, children aged 6–15 years are enrolled in primary school, while teens aged 15–19 attend secondary school. Regarding age distribution, 268 teachers were aged between 25 and 30 years, 899 between 31 and 40 years, 1003 between 41 and 50 years, and 806 over 51 years, with 436 participants not disclosing their age.

3.3. Measures

To evaluate teachers’ opinions on the importance and frequency of feedback and answers to RQ1 and H1, we used a questionnaire that consisted of eight questions, five of which were closed and three were open-answer questions.

To evaluate the usability of the “Compliments and Comments Tool” and answer RQ2, H2, and H3, this study utilized an adapted version of the System Usability Scale (SUS) [79] and the Technology Acceptance Model (TAM) [75,82], aligned with ISO 9241-11 standards [74]. These instruments were adapted to the educational context and specifically focused on the application of the tool to teachers. The measures assessed the ease of use, perceived usefulness, and efficiency of the feedback tool along with the importance of various skill developments facilitated by the tool. The demographic questions were related to gender, age group, and the level of school taught by teachers. The questionnaire consisted of nine questions, five of which were closed, and four questions were answered using a 5-point Likert scale.

The questionnaires were developed through a rigorous process involving multiple stages. Initially, a pool of items was generated based on a comprehensive review of the relevant literature and existing scales on teacher feedback, student monitoring, and usability. Subsequently, we assembled a diverse team of experts to ensure a comprehensive and precise evaluation of the “Compliments and Comments Tool” through the development of questionnaires. This team comprised distinguished academics and practitioners from various relevant fields including educational psychology, computer science, digital pedagogy, and educational technology research. An educational psychologist, with over 30 years of experience, provided expertise in guiding the psychological and pedagogical validity of our questions. Additionally, a Professor with a Ph.D. in Computer Science and specialization in digital pedagogy ensured that the technical content of the questionnaire accurately reflected the current technological advancements. Furthermore, a Ph.D. candidate researching Educational Technology contributed expertise in digital learning environments to align our instrument with cutting-edge educational technology practices. We also collaborated closely with a team from the “e-Asistent” company, which has been at the forefront of educational system development for over 25 years. Their insights were crucial in refining the aspects of the “Compliments and Comments Tool” within the questionnaire to ensure real-world applications and utility. Their understanding of the user experience and system functionality helped tailor our questions to effectively probe the efficacy and reception of the tool in educational settings. This collaborative effort ensured that the questions were relevant and grounded in theoretical and practical insights.

“Compliments and Comments Tool” Description

The “Compliments and Comments Tool” is a component of the “e-Asistent” information system designed for comprehensive student monitoring and feedback. The tool includes a Compliments tab, which is divided into nine sub-categories. The sub-categories, along with their English translations, are as follows: Razvoj miselnih spretnosti—Development of thinking skills; Komunikacijske spretnosti—Communication skills; Vztrajnost, motiviranost in ciljna usmerjenost—Perseverance, motivation, and goal orientation; Zanesljivost, odgovornost in organiziranost—Reliability, responsibility, and organization; Strategije reševanja problemov—Problem-solving strategies; Socialne spretnosti—Social skills; Radovednost, ustvarjalnost in podjetnost—Curiosity, creativity, and entrepreneur-

ship; Odličnost—Excellence; and Moja pohvala—My compliment (Figure 2). Below the sub-categories, there is a text box where teachers can write specific comments related to the selected category. Additionally, the list of students is shown at the bottom, allowing teachers to select a student and provide individualized feedback.

The Suggestions for Improvements tab focuses on providing formative feedback and includes five sub-categories, such as activity/passivity, disruptive behavior, and task performance (Figure 3). The sub-categories, along with their English translations, are as follows: Aktivnost/pasivnost pri pouku—Activity/passivity in class; Moteče vedenje—Disruptive behavior; Moj predlog za izboljšavo—My suggestion for improvement; Opravljanje nalog—Task completion; and Agresivno vedenje—Aggressive behavior. Below the sub-categories, the user interface follows the same structure as for the Compliments tab. The tool also offers analytics capabilities, allowing teachers and school administrators to monitor overall classroom and school behavior (Figures 4 and 5). Figure 4 shows the ratio of compliments and needed improvements in the form of a pie chart with the navigation pane on the left side, listing different classes and grades. At the bottom, there is a section providing specific examples of feedback given to individual students, including the feedback type, student ID, date, time, and teacher comments, for example, “Danes si zelo motil pouk, ko si se pogovarjal s svojim prijateljem. Prosim, če se ne ponovi več” —“Today you were very disruptive in class while talking to your friend. Please do not let it happen again” and “Danes si super dvigoval roko in odgovarjal na vprašanja! Le tako naprej!” —“Today you raised your hand and answered questions very well! Keep it up!” Figure 5 shows the overall view of the schools’ ratio of compliments and needed improvements with a pie chart, a trend, and at the bottom, the latest compliments and needed improvements, structured the same way as at the classroom level.

3.4. Data Analyses

The data analysis aimed to address the research questions (RQ1 and RQ2) and hypotheses (H1, H2, H3) posed in this study, focusing on teachers’ opinions on the importance and frequency of feedback, as well as the usability of the “Compliments and Comments Tool”.

A mixed-methods approach was used to answer RQ1 and test H1. Quantitative data analysis involved calculating the means, frequencies, and percentages to summarize the participants’ responses. Due to the non-normal distribution of the data, as indicated by the Shapiro–Wilk test, non-parametric statistical methods were employed. Specifically, the Mann–Whitney U test and the Wilcoxon rank-sum test were employed to compare responses between genders, and the Kruskal–Wallis H test was used to compare responses between age groups. The effect sizes (Cohen’s d) were calculated to assess the magnitude of the differences. The qualitative data were analyzed using thematic analysis, where open-ended responses were processed and categorized into themes using Microsoft Excel to provide a detailed understanding of teachers’ perceptions of feedback practices.

For RQ2 and the associated hypotheses (H2 and H3), descriptive and inferential statistical techniques were applied. Descriptive statistics, including means, frequencies, and percentages, were used to summarize responses regarding the usability of the tool. The distribution characteristics of the data were examined using skewness and kurtosis values to understand overall response tendencies. The Mann–Whitney U and Kruskal–Wallis H tests were applied to explore variations in perceptions of the tool across different demographic groups, including age and school type (primary vs. secondary). Item difficulty and discrimination analyses were conducted to evaluate the tool’s effectiveness. Item difficulty was assessed by calculating the proportion of respondents who rated items positively (scores of 4 or 5). Item discrimination was measured by correlating individual item scores with total scores to determine the degree to which items differentiated between satisfied and less-satisfied users.

1.A

Pohvale

Komentari

Potrebne izboljšave

Izberite vrsto pohvale in napišite komentar:

Razvoj miselnih spretnosti

Strategije reševanja problemov

Komunikacijske spretnosti

Socialne spretnosti

Vztrajnost, motiviranost in ciljna usmerjenost

Radovednost, ustvarjalnost in podjetnost

Zanesljivost, odgovornost in organiziranost

Odličnost

Moja pohvala

Napišite komentar k pohvali...

Potrdi

Prekliči

Seznam učencev

1. Učenec 163

2. Učenec 164

3. Učenec 165

4. Učenec 166

5. Učenec 167

6. Učenec 168

1.A

→ Class

Pohvale

Komentari

Potrebne izboljšave

Razvoj miselnih spretnosti

Strategije reševanja problemov

Komunikacijske spretnosti

Socialne spretnosti

Vztrajnost, motiviranost in ciljna usmerjenost

Radovednost, ustvarjalnost in podjetnost

Zanesljivost, odgovornost in organiziranost

Odličnost

Moja pohvala

Napišite komentar k pohvali...

Potrdi

Prekliči

Seznam učencev

1. Učenec 163

2. Učenec 164

3. Učenec 165

Figure 2. Compliments tab of the tool.

Pohvale Komentari **Potrebne izboljšave**

Izberite vrsto potrebne izboljšave in napišite komentar:

Aktivnost/pasivnost pri pouku

Opravljanje nalog

Moteče vedenje

Agresivno vedenje

Moj predlog za izboljšavo

Napišite komentar k potrebni izboljšavi...

Potrdi Prekliči

S seznama izberite enega ali več učencev

Seznam učencev

	1. Učenec 163
	2. Učenec 164
	3. Učenec 165
	4. Učenec 166
	5. Učenec 167
	6. Učenec 168

Pohvale Komentari **Potrebne izboljšave** → Compliments, Comments and Suggestions for Improvements tabs

Izberite vrsto potrebne izboljšave in napišite komentar:

Aktivnost/pasivnost pri pouku

Opravljanje nalog

Moteče vedenje

Agresivno vedenje

Moj predlog za izboljšavo

→ Suggestions for Improvements tab sub-categories

Napišite komentar k potrebni izboljšavi... → Written comment

Potrdi Prekliči

S seznama izberite enega ali več učencev

Seznam učencev

	1. Učenec 163
	2. Učenec 164
	3. Učenec 165

→ List of students

Figure 3. Suggestions for Improvements tab of the tool.

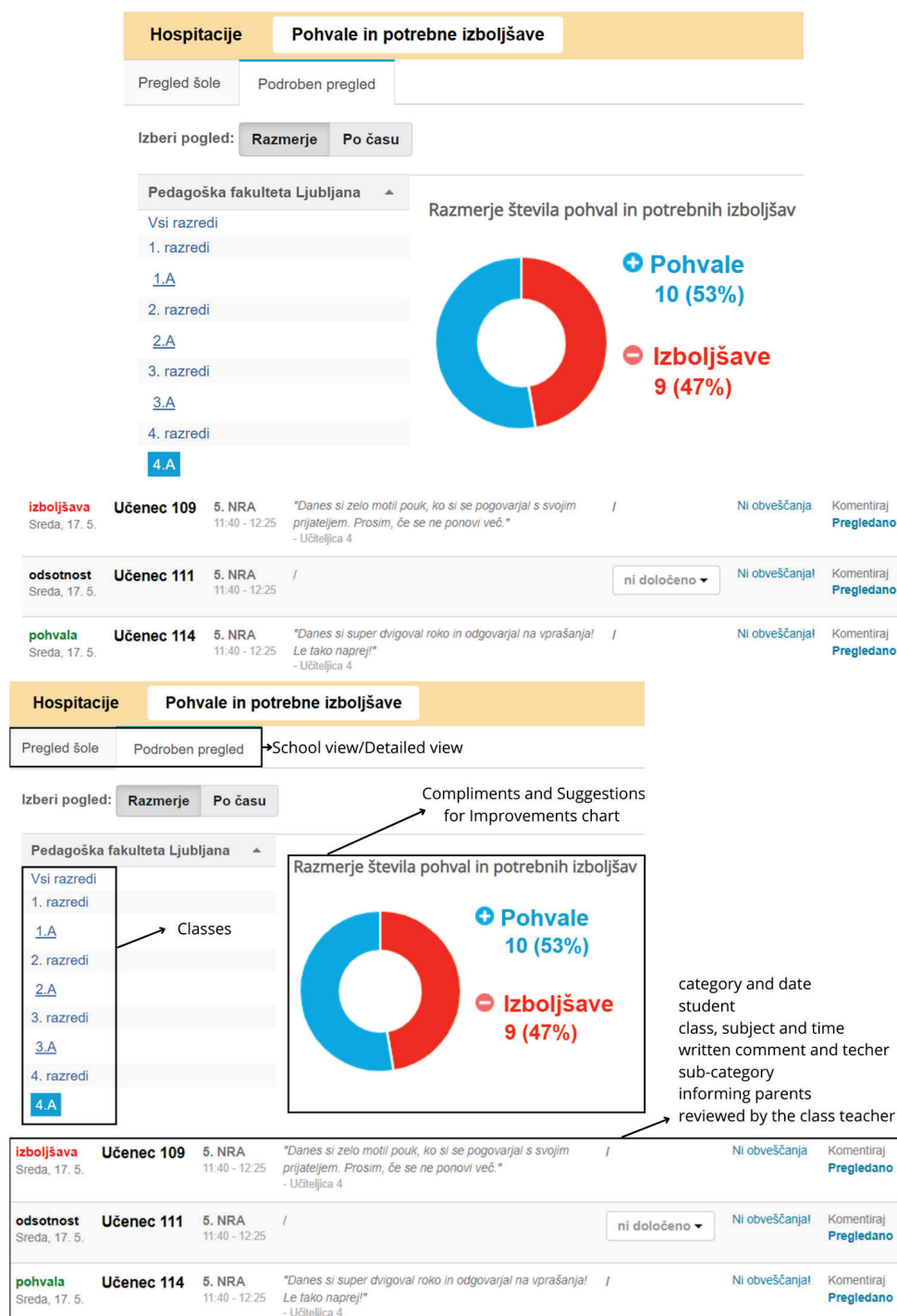


Figure 4. Overall view of the class (examples from the fictitious testing environment).

Factor analysis was conducted to test the construct validity of the usability questionnaire. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.943, indicating that the sample size was sufficient for factor analysis. Bartlett’s Test of Sphericity was significant ($\chi^2 = 87,571.99$, $df = 703$, $p < 0.001$), confirming the suitability of the data for this analysis. Principal component analysis revealed seven factors with eigenvalues greater than 1, explaining 70.75% of the total variance, with the first factor accounting for 21.18% of the variance. The subsequent factors explained 16.70% and 2.85% of the variance. The commonalities were all above 0.5, confirming that each item shared some common variance with the other items. Factor analysis revealed a coherent structure with seven factors representing different dimensions of teachers’ experiences and perceptions of using

the technology-enhanced feedback tool. These factors include ease of use, importance of skills development, usefulness and efficiency, behavioral observations, school type, age, and education, as well as teaching experience and dealing with student behavior, which supports the validity of the questionnaire.

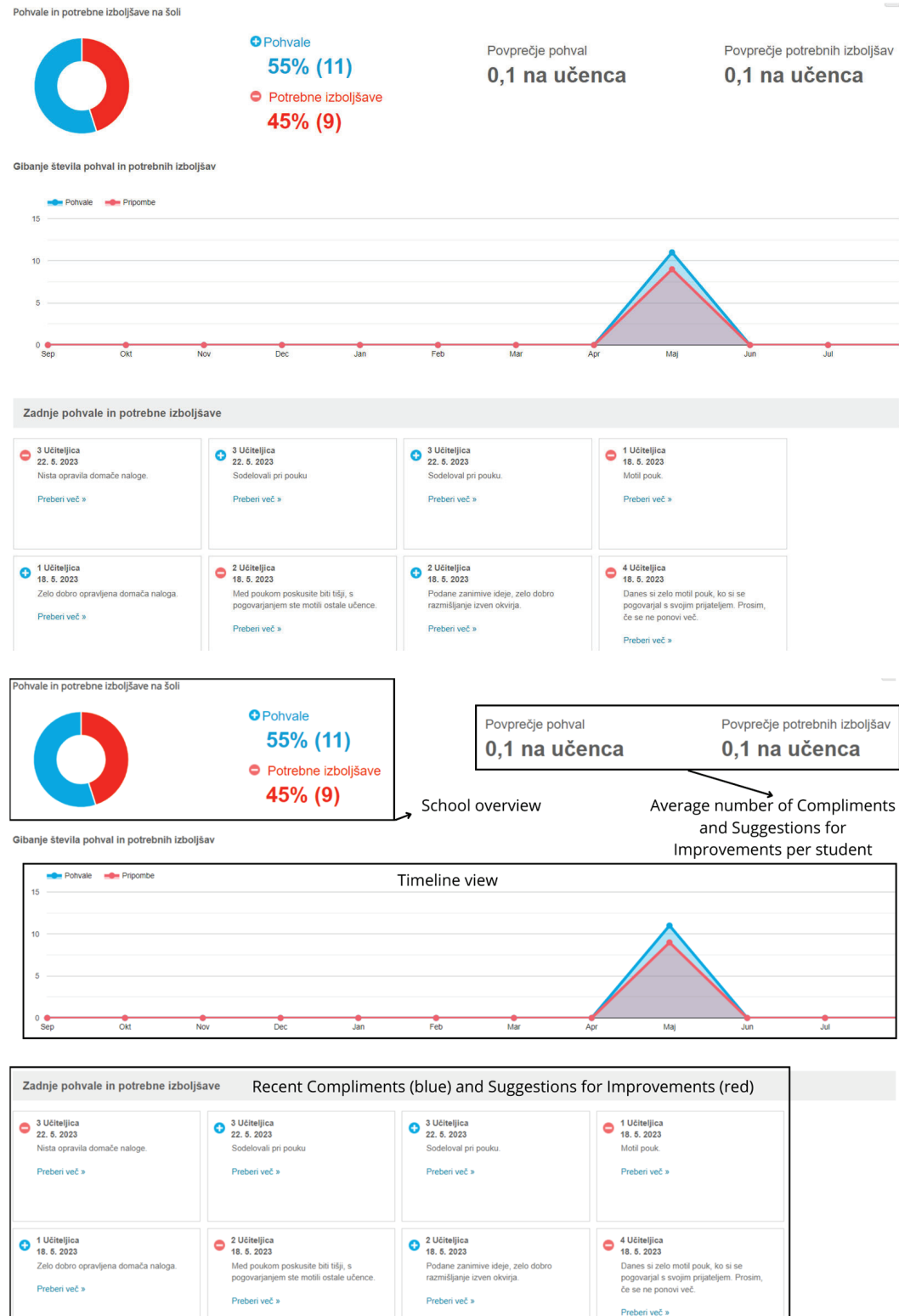


Figure 5. Overall view of the school (e.g., from a fictitious testing environment).

The internal consistency and reliability of the questionnaire items were confirmed using Cronbach's alpha, which indicated high internal consistency ($\alpha = 0.93$ for the first questionnaire and $\alpha = 0.96$ for the Likert-type scales measuring the tool's usefulness in the second questionnaire).

To ensure instrument validity, the questions and scales were carefully aligned with the research objectives. Triangulation was employed by collecting data from a diverse range of schools, considering factors such as the school level and location. Objectivity was maintained by providing standardized instructions and ensuring consistent conditions for completing the questionnaires.

Sensitivity in the data was addressed using 5-point Likert-type scales in the usability questionnaire, allowing for nuanced responses. Appropriate response specifications for the closed questions in both questionnaires ensured the collection of precise and relevant data.

4. Results

4.1. Teachers' Opinions on the Importance and Frequency of Feedback

This section addresses Research Question 1 (RQ1) and Hypothesis 1 (H1), focusing on teachers' views of the importance and frequency of providing feedback to parents and students. Data were collected using five closed and three open-ended questions.

Importance of sharing feedback with parents

The vast majority (93.6%) of teachers agreed that providing feedback to parents is crucial for fostering a stimulating learning environment.

Open-ended responses, categorized into three themes, revealed that 59.0% of teachers believed regular feedback was essential for informing parents about their child's progress and behavior, facilitating cooperation among teachers, parents, and students. Additionally, 20.5% stressed the importance of timely parental intervention, while 20.5% felt that direct communication or student responsibility for relaying feedback was preferable (Table 1).

Table 1. Content response categories of open-ended teacher responses on why it is important to provide feedback to parents.

Content Response Categories		<i>f</i>	<i>f</i> %
Parents are regularly informed about their child's work and behavior. Facilitates cooperation between teachers, parents, and the student.	+	23	59.0
Parents can intervene in a timely and appropriate manner. Enables timely resolution of problems and conflicts.	+	8	20.5
Personal contact is better; the child communicates information personally; it is the child's responsibility.	—	8	20.5
Total		39	100.0

Frequency of feedback

Regarding feedback frequency, 76.6% of the teachers favored weekly over daily updates, citing that weekly feedback balances the need for timely intervention without overwhelming parents.

The qualitative responses highlighted that 39.4% viewed weekly feedback as sufficient for tracking student behavior and academic progress. In contrast, 22.7% supported daily feedback for immediacy, while 21.2% argued that students were responsible for communicating with their parents (Table 2).

Table 2. Content response categories of open-ended teacher responses on weekly versus daily feedback.

Content Response Categories	<i>f</i>	<i>f</i> %
Weekly feedback is frequent enough and not burdensome for parents.	26	39.4
Daily feedback is more effective, up to date, and may lose relevance after a few days.	15	22.7
The child should trust parents and child responsibility should be encouraged.	14	21.2
Too frequent provision reduces its value.	5	7.6
All problems should be solved verbally.	3	4.5
Even less frequent than weekly (monthly, quarterly) would be sufficient.	2	3.0
Not enough time (on the teacher's side) for daily intervention.	1	1.5
Total	66	100.0

Preferred timing for recording feedback

Most teachers indicated a preference for providing feedback during or immediately after lessons (30.4%) or at the end of the workday (28.3%), suggesting a preference for prompt feedback (Table 3).

Table 3. Teachers' opinions on when it would be easiest for them to write feedback.

I Would Find It Easiest to Write Down Feedback for Students as Follows:	<i>f</i>	<i>f</i> %
(1) During or immediately after the lesson.	28	30.4
(2) At the end of the last lesson of the day.	26	28.3
(3) In the evening of the same day.	13	14.1
(4) Once at the end of the work week.	15	16.3
(5) I would not take the time to write down feedback.	10	10.9
Total	92	100.0

Frequency of recording feedback

In terms of recording feedback, 64.8% of the teachers advocated for daily or continuous documentation, underscoring the importance of detailed records (Table 4).

Table 4. Teachers' views on how often feedback should be recorded.

Feedback to Students Should be Recorded as Follows:	<i>f</i>	<i>f</i> %
(1) Daily or ongoing.	59	64.8
(2) Once a month.	22	24.2
(3) Once per assessment period.	5	5.5
(4) Once a year.	1	1.1
(5) No feedback needs to be recorded.	4	4.4
Total	91	100.0

4.2. Differences between Genders and Age Groups in Teachers' Opinions about the Importance and Frequency of Providing Feedback

In H1, we hypothesized that there would be no differences between genders and age groups in teachers' opinions about the importance and frequency of providing feedback to students and sending it to parents.

The Shapiro–Wilk test revealed that none of the question responses followed a normal distribution ($p < 0.05$), justifying the use of non-parametric tests for subsequent analyses.

The Mann–Whitney U test and Wilcoxon rank-sum test were used to compare responses between male and female teachers. The results indicated no significant differences in responses across all questions ($p > 0.05$), except for a marginally nonsignificant difference in question on weekly versus daily feedback ($p = 0.041$, not statistically significant when considering multiple comparisons). The effect sizes (Cohen’s d) were calculated to assess the magnitude of the differences. All questions showed negligible effect sizes, except for the question on the most appropriate time to write feedback (Cohen’s $d = -0.44$). However, this difference was not statistically significant and was considered small to moderate, suggesting minimal practical significance.

The Kruskal–Wallis H test was used to examine the differences in responses across various age groups. The analysis revealed no statistically significant differences for any question ($p > 0.05$), indicating that age did not significantly influence teachers’ opinions regarding the importance and frequency of feedback.

The data suggest that teachers, regardless of gender or age, generally agree on the importance of feedback and maintain similar opinions regarding their frequency. Therefore, the findings support H1, indicating that demographic variables such as gender and age do not significantly impact teachers’ views of feedback practices. It is important to note that the results are based on teachers’ self-reported opinions and may be subject to individual bias or contextual factors. However, these findings provide insights into teachers’ perspectives on feedback and can inform educational practices and policies related to parent–teacher communication and student self-regulation.

4.3. Usability of the Technology-Enhanced Feedback Provision Tool

The usability of the “Compliments and Comments Tool” was evaluated on the basis of three key aspects: effectiveness, ease of use, ease of learning, and satisfaction. The following results address Research Question 2 (RQ2), which explores the extent of teachers’ satisfaction with the tool’s functionality.

4.3.1. Teachers’ Opinions of the Effectiveness of the Compliments and Comments Tool

Teachers evaluated the effectiveness of the tool based on six statements using a 5-point Likert scale. The responses are summarized in Table 5.

Table 5. Teachers’ opinions on the effectiveness of the “Compliments and Comments Tool”.

		Effectiveness of the Compliments and Comments Tool					Sum	Me	Mo	$\bar{X}$	σ
		1	2	3	4	5					
Is useful.	f	129	196	808	1126	1153	3412	4.0	5	3.9	1.1
	$f\%$	3.8	5.7	23.7	33.0	33.8	100.0				
It helps me to be more efficient.	f	318	477	1031	983	600	3409	3.0	3	3.3	1.2
	$f\%$	9.3	14.0	30.2	28.8	17.6	100.0				
It gives me a better overview of what is happening in the classroom.	f	298	412	888	1006	808	3412	4.0	4	3.5	1.2
	$f\%$	8.7	12.1	26.0	29.5	23.7	100.0				
It allows me to give feedback to students and parents.	f	229	318	880	1100	885	3412	4.0	4	3.6	1.2
	$f\%$	6.7	9.3	25.8	32.2	25.9	100.0				
It allows me to save time.	f	397	463	884	885	813	3412	3.0	3	3.4	1.3
	$f\%$	11.6	13.6	25.9	25.1	23.8	100.0				
It enables me to do what I expect to do.	f	310	448	1133	922	599	3412	3.0	3	3.3	1.2
	$f\%$	9.1	13.1	33.2	27.0	17.6	100.0				

1—strongly disagree; 5—strongly agree.

Frequency analysis showed that most teachers rated the usability and effectiveness of the tool positively, with average scores ranging from 3.3 to 3.9 out of 5. The data showed a left-skewed distribution (negative skewness values ranging from -0.3 to -0.8), indicating a tendency towards higher ratings. The flat distribution (kurtosis values close to zero) suggests a spread-out range of responses, with mode values typically at 3 or 4, underscoring a generally favorable reception of the tool among teachers despite some ambivalence regarding its efficiency and time-saving capabilities.

Item difficulty and discrimination analyses were conducted to further evaluate the effectiveness of the tool. Item difficulty analysis revealed that the proportion of respondents rating the items as positive (4 or 5) ranged from 61.28% ("Allows giving feedback to students and parents") to 74.85% ("Saves time"). This indicates a generally high level of satisfaction with the tool's effectiveness.

Item discrimination, measured by the correlation between individual item scores and the total score, demonstrated a strong differentiation between satisfied and less satisfied users. Discrimination indices ranged from 0.743 ("Saves time") to 0.879 ("Helps me to be more efficient"), with the highest values indicating that these items effectively distinguished between respondents with differing overall levels of satisfaction.

These analyses confirm a broadly positive perception of the effectiveness of the tool among teachers, highlighting areas of strength such as perceived usefulness and efficiency. However, the analysis also suggests potential areas for improvement, particularly in terms of time-saving capabilities and efficiency, as indicated by the relatively lower item difficulty and discrimination scores in these areas.

4.3.2. Teachers' Opinion on the Ease of Use of the Compliments and Comments Tool

The usability of the "Compliments and Comments Tool" was further evaluated based on ease of use, which is critical given the limited classroom time during which teachers must provide feedback. Teachers' responses were collected on a 5-point scale, assessing various ease-of-use aspects, including simplicity, user-friendliness, and the need for instructions (Table 6).

Table 6. Teachers' opinions on the ease of use of the "Compliments and Comments Tool".

		Ease of Use of Compliments and Comments Tool					Sum	Me	Mo	$\bar{X}$	σ
		1	2	3	4	5					
It is easy to use.	<i>f</i>	117	153	635	1144	1362	3411	4.0	5	4.0	1.0
	<i>f</i> %	3.4	4.5	18.6	33.5	39.9	100.0				
It is user-friendly.	<i>f</i>	132	181	706	1184	1209	3412	4.0	5	3.9	1.1
	<i>f</i> %	3.9	5.3	20.7	34.7	35.4	100.0				
It requires few steps to make an entry.	<i>f</i>	146	256	717	1169	1124	3412	4.0	4	3.8	1.1
	<i>f</i> %	4.3	7.5	21.0	34.3	32.9	100.0				
It allows user flexibility.	<i>f</i>	155	257	908	1137	954	3411	4.0	4	3.7	1.1
	<i>f</i> %	4.5	7.5	26.6	33.3	28.0	100.0				
I do not need written instructions to use it.	<i>f</i>	112	159	587	1073	1481	3412	4.0	5	4.1	1.0
	<i>f</i> %	3.3	4.7	17.2	31.4	43.4	100.0				
I do not detect inconsistencies during use.	<i>f</i>	143	207	958	1148	956	3412	4.0	4	3.8	1.1
	<i>f</i> %	4.2	6.1	28.1	33.6	28.0	100.0				
It makes it easy to correct errors.	<i>f</i>	143	192	718	1130	1228	3411	4.0	5	3.9	1.1
	<i>f</i> %	4.2	5.6	21.0	33.1	36.0	100.0				

1—strongly disagree; 5—strongly agree.

Users are more quickly and easily able to adopt the tool, which is easy to use and allows instant applications without written instructions or lengthy learning curves. User acceptance is also influenced by the functionality and design of the user interface. The user interface should be clear and understandable, which should enable the user to perform tasks quickly and efficiently. The user should make as few mistakes as possible during the use of the application because of misunderstandings or confusion in the user interface. In technology, this is called making an application or user interface “user-friendly” [94]. It is crucial for an application user to have simple access to self-correction features after making mistakes.

Frequency analysis revealed that most teachers rated the ease of use of the “Compliments and Comments Tool” positively, with average scores ranging from 3.7 to 4.1 out of five, although some teachers noted a need for more flexibility in feedback options. The data exhibited a left-skewed distribution (negative skewness values ranging from -0.6 to -1.1), indicating a tendency towards higher ratings. The relatively flat or negative kurtosis values suggest a diverse range of responses, with mode values typically at 4 or 5, underscoring a generally favorable reception of the tool’s ease of use among teachers (Table 6).

To further assess the ease of use of the tool, item difficulty and discrimination analyses were performed. Item difficulty analysis showed that the proportion of respondents who rated the items as positive (4 or 5) ranged from 61.3% (“It allows user flexibility”) to 74.9% (“I do not need written instructions to use it”). This indicates a generally high level of satisfaction with the ease of use of the tool. Item discrimination, measured by the correlation between individual item scores and the total score, demonstrated a strong differentiation between more and less satisfied users. Discrimination indices ranged from 0.752 (“I do not need written instructions to use it”) to 0.877 (“It is user-friendly”), with the highest values indicating that these items effectively distinguished between respondents with differing overall perceptions of ease of use.

These analyses confirm a broadly positive perception of the tool’s ease of use among teachers, highlighting strengths such as its perceived ease of use and minimal need for instruction. However, the analysis also suggested areas for improvement, particularly in aspects related to user flexibility and the ability to correct errors, as indicated by the relatively lower item difficulty and discrimination scores in these areas.

4.3.3. Teachers’ Opinion on Ease of Learning to Use and Satisfaction with the Compliments and Comments Tool

For new technologies to be successfully adopted in educational settings, they must be easy to learn and satisfy user expectations. The ease of learning a new tool is critical as it influences whether teachers will continue using it and recommend it to others. The “Compliments and Comments Tool” was evaluated based on these criteria using a 5-point Likert scale (Table 7).

Frequency analysis revealed that most teachers rated the ease of learning and satisfaction with the “Compliments and Comments Tool” positively, with average scores ranging from 3.8 to 4.2 out of 5. The data exhibited a left-skewed distribution, as evidenced by the negative skewness values, suggesting a tendency towards higher ratings. The kurtosis values, varying across items (from -0.081 to 1.616), indicated distributions with sharper peaks for some items (e.g., “I quickly learned to use the tool” and “I can remember how to use the tool”) and more normal distributions for others (e.g., satisfaction and recommendation likelihood). This indicates a generally favorable perception among teachers regarding the tool’s ease of learning and overall satisfaction.

Item difficulty and discrimination analyses were conducted to further assess the tool’s ease of learning and satisfaction. Item difficulty analysis showed that the proportion of respondents rating the items as positive (4 or 5) ranged from 64.5% (“I would recommend the tool to a colleague teacher”) to 80.4% (“I can remember how to use the tool”). This finding suggests a high level of satisfaction with these aspects of the tool. Item discrimination, measured by the correlation between individual item scores and the total score,

demonstrated a strong differentiation between more and less satisfied users. Discrimination indices ranged from 0.645 (“I would recommend the tool to a colleague teacher”) to 0.840 (“I am satisfied with the tool”), indicating that these items effectively distinguished between respondents with varying levels of satisfaction.

Table 7. Teachers’ opinions on the ease of learning to use and satisfaction with the “Compliments and Comments Tool”.

		Ease of Learning to Use and Satisfaction with the Compliments and Comments Tool					Sum	Me	Mo	$\bar{X}$	σ
		1	2	3	4	5					
I quickly learned to use the tool.	<i>f</i>	116	93	509	1021	1676	3412	4.0	5	4.2	1.0
	<i>f</i> %	3.4	2.7	14.8	29.9	49.1	100.0				
I can remember how to use the tool.	<i>f</i>	99	93	477	1039	1704	3412	4.0	5	4.2	1.0
	<i>f</i> %	2.9	2.7	14.0	30.5	49.9	100.0				
I am satisfied with the tool.	<i>f</i>	178	201	758	1137	1128	3411	4.0	4	3.8	1.1
	<i>f</i> %	5.5	5.9	22.2	33.3	33.1	100.0				
I would recommend the tool to a colleague teacher.	<i>f</i>	219	224	768	1061	1140	3412	4.0	5	3.8	1.2
	<i>f</i> %	6.4	6.6	22.5	31.1	33.4	100.0				

1—strongly disagree; 5—strongly agree.

These analyses confirm a broadly positive perception of the tool’s ease of learning and user satisfaction among teachers, highlighting strengths such as the learning curve (“I quickly learned to use the tool”) and remembering how to use the tool. However, the analysis also suggested areas for improvement, particularly in enhancing satisfaction and the likelihood of recommending the tool, as indicated by the relatively lower item difficulty and discrimination scores in these areas.

Overall, the analyses of the usability of the tool across these three dimensions—effectiveness, ease of use, and ease of learning and satisfaction—confirm a generally positive perception of the “Compliments and Comments Tool” among teachers. The tool is well received for its usability and functionality, although specific areas such as efficiency, user flexibility, and comprehensive user satisfaction present opportunities for further refinement and enhancement.

4.4. Statistically Significant Differences in Opinions on Usefulness of the Tool According to the Age Group of Participants and Type of School Participants Teach in (Primary/Secondary)

We hypothesized that there would be differences in system usability satisfaction among teachers based on their age group (H2) and type of school (primary or secondary) (H3).

4.4.1. Statistically Significant Differences between the Age Groups

Hypothesis H2 sought to explore the impact of different age groups on teachers’ evaluations of the usability of a feedback tool in promoting self-regulation and learning strategies. A Kruskal–Wallis H test was conducted to determine whether there were differences in perceptions of the “Compliments and Comments Tool” between different age groups (20–30 years, 31–40 years, 41–50 years, and 51 years and older) across various variables.

Differences between the age groups and opinions on the effectiveness of the tool

Statistically significant differences were found between the age groups of the participants and their opinions on the effectiveness of the tool.

Regarding the general perception of the usefulness of the tool and its capability to facilitate feedback to students and parents, there were no statistically significant differences among the age groups ($p > 0.05$). This indicates that teachers across all age groups gen-

erally perceived the tool as equally useful and effective in providing feedback. However, significant differences were observed in the following areas:

- **Effectiveness in enhancing efficiency:** The test showed a statistically significant difference, with a Kruskal–Wallis H value of 8.373 and a *p*-value of 0.039 (Table 8). This suggests that different age groups perceive the tool’s efficiency benefits differently, with some age groups finding it more effective than others in enhancing their efficiency. Specifically, teachers aged 31–40 and 41–50 years reported higher mean ranks (1445.25 and 1506.57, respectively) than those aged 20–30 (mean rank 1404.02) and 51 years and older (mean rank 1536.82).
- **Providing classroom overview:** There was a statistically significant difference in perceptions of the tool providing better classroom oversight, with a Kruskal–Wallis H value of 8.045 and a *p*-value of 0.045 (Table 8). This indicates that the tool’s ability to offer insights into classroom activities differs across age groups. Teachers aged 31–40 years (mean rank 1461.60) and 41–50 years (mean rank 1516.85) rated this aspect higher than those aged 20–30 years (mean rank 1377.37) and those aged 51 years and older (mean rank 1520.18).
- **Time saving:** The tool’s ability to save teachers’ time showed a significant difference among age groups, with a Kruskal–Wallis H value of 13.817 and a *p*-value of 0.003 (Table 8). This implies that some age groups perceive the tool as more effective in saving time than others do. Teachers aged 31–40 years (mean rank 1439.28), 41–50 years (mean rank 1523.73), and 51 years and older (mean rank 1540.52) reported higher mean ranks than those aged 20–30 years (mean rank 1365.31).
- **Meeting expectations:** The perception of the tool enabling teachers to accomplish their expected tasks also showed a statistically significant difference, with a Kruskal–Wallis H value of 13.520 and a *p*-value of 0.004 (Table 8). This finding suggests variability in how different age groups perceive the tool’s ability to meet their expectations. Teachers aged 31–40 years (1473.14), 41–50 years (mean rank 1502.99), and 51 years and older (mean rank 1540.30) reported higher mean ranks than those aged 20–30 years (mean rank 1330.02).

Table 8. Kruskal–Wallis H test results of differences between age groups and opinions on the effectiveness of the tool.

Variable	Kruskal–Wallis H	<i>p</i>
Is useful.	6.262	0.100
It helps me to be more efficient.	8.373	0.039
It gives me a better overview of what is happening in the classroom.	8.045	0.045
It allows me to give feedback to students and parents.	1.421	0.701
It allows me to save time.	13.817	0.003
It enables me to do what I expect to do.	13.520	0.004

Significant differences are marked bold.

The results revealed that age groups significantly impacted perceptions of the feedback tool in terms of enhancing efficiency, providing classroom oversight, saving time, and meeting expectations. Specifically, teachers aged 31–40 years and 41–50 years tended to have more favorable perceptions of the tool’s effectiveness in enhancing efficiency and providing classroom oversight. Teachers aged 31–40 years, 41–50 years, and 51 years and older perceived the tool as more effective in saving time and meeting their expectations compared to younger teachers aged 20–30 years.

These findings highlight the importance of considering age-related differences when implementing and training teachers in the use of feedback tools. Tailored support and training programs that address the specific needs of younger teachers (20–30 years old)

may help enhance their perceptions and utilization of the tool, ultimately leading to more effective and efficient feedback processes across all age groups.

Differences between the age groups and opinions on the ease of use of the tool

Statistically significant differences were also found between the age groups of the participants and their opinions on the ease of use of the tool.

The Kruskal–Wallis H test results indicate that perceptions of the feedback tool’s ease of use, user-friendliness, required steps for entry, flexibility, consistency, and ease of correcting errors do not significantly differ among age groups. However, there was a statistically significant difference in perceptions of the tool that did not require written instructions among different age groups, with a Kruskal–Wallis H value of 21.413 and a p -value < 0.001 (Table 8). Younger teachers aged 20–30 years (mean rank 1557.85) and those aged 31–40 years (mean rank 1552.24) found the tool easier to use without written instructions compared to older age groups. Thus, we conclude that older teachers who do not have extensive knowledge of digital technology need written guidance regarding the technical use of the tool (Table 9).

Table 9. Kruskal–Wallis H test results of differences between age groups and opinions on the ease of use of the tool.

Variable	Kruskal–Wallis H	p
It is easy to use.	4.737	0.192
It is user-friendly.	1.937	0.586
It requires few steps to make an entry.	4.052	0.256
It allows user flexibility.	1.690	0.639
I do not need written instructions to use it.	21.413	<0.001
I do not detect inconsistencies during use.	4.252	0.236
It makes it easy to correct errors.	0.939	0.816

Significant difference is marked bold.

These findings highlight the importance of addressing the specific needs of different age groups, particularly in providing adequate instruction and support to ensure that all teachers can use the tool effectively.

Differences between the age groups and opinions on the ease of learning and satisfaction with the tool

Statistically significant differences were also found between the age groups of the participants and their opinions on the ease of learning and satisfaction with the tool.

The Kruskal–Wallis H test results indicated significant differences in perceptions of the tool’s ease of use and user-friendliness among different age groups of teachers. However, there were no significant differences in perceptions regarding the number of steps required to enter and the flexibility provided by the tool.

There was a statistically significant difference in perceptions of the tool being easy to use among different age groups, with a Kruskal–Wallis H value of 35.702 and a p -value < 0.001 . Younger teachers aged 20–30 years and 31–40 years (mean ranks 1559.09 and 1518.89, respectively) find the tool easier to use than older teachers aged 51 years and older. This suggests that younger teachers adapt to the tool more readily than their older counterparts. There was also a statistically significant difference in perceptions of the tool being user-friendly among different age groups, with a Kruskal–Wallis H value of 27.529 and a p -value < 0.001 . Teachers aged 20–30 years and 31–40 years perceived the tool to be more user-friendly than those aged 51 years and older (Table 10).

Table 10. Kruskal–Wallis H test results of differences between age groups and opinions on the ease of learning and satisfaction with the tool.

Variable	Kruskal–Wallis H	<i>p</i>
I quickly learned to use the tool.	35.702	<0.001
I can remember how to use the tool.	27.529	<0.001
I am satisfied with the tool.	0.504	0.918
I would recommend the tool to a colleague teacher.	2.458	0.483

Significant differences are marked bold.

4.4.2. Statistically Significant Differences between Educational Levels

Hypothesis H3 sought to explore the impact of educational level (primary versus secondary school) on teachers' evaluations of the usability of a feedback tool in promoting self-regulation and learning strategies. This objective was to analyze variations in the usability of the feedback tool between primary and secondary education levels, acknowledging potential disparities in the emphasis on self-regulatory skills and learning strategies at these respective levels.

The Mann–Whitney U test was conducted to compare the perceptions of primary and secondary school teachers regarding the usability of the tool. The results showed no statistically significant differences between the two groups for any of the measured variables ($p > 0.05$). Teachers from both the primary and secondary schools provided similar evaluations of the tool's effectiveness, ease of use, and overall satisfaction. This implies that the tool is perceived similarly by teachers across different school types, which could mean that training and support efforts do not need to be differentiated based on school type (primary vs. secondary). We thus reject hypothesis H3.

These findings underscore the importance of addressing the specific needs of different age groups, particularly in providing adequate instruction and support to ensure that all teachers can use the tool effectively. Tailored training and support for older teachers can help bridge this gap and improve their ease of use and satisfaction with the tool.

5. Discussions

The integration of TEF systems into education has shown promising potential for improving teaching effectiveness and student outcomes. This study investigated teachers' views on the importance and frequency of feedback and the usability of the “Compliments and Comments Tool”, focusing on teachers' satisfaction and their perceptions of its impact on student self-regulation. This tool was designed to facilitate written feedback for students in the Slovenian education context. Our findings provide valuable insights into the significance of feedback in the educational process and underscore the necessity of user-centered design in educational technology.

5.1. Importance and Frequency of the Feedback Provided to Students

The surveyed teachers overwhelmingly recognized the critical role of feedback in fostering a stimulating learning environment and supporting student academic success [4,95,96]. Continuous feedback significantly enhances student performance, motivation, and self-regulation [2,24,70,97]. In digital learning environments, timely and positive feedback is particularly influential as it helps students adjust their learning strategies and enhance their self-efficacy [98]. Gambari et al. [2] found that consistent feedback correlates with improved academic performance and engagement, underscoring the need for effective feedback mechanisms in educational technology.

Regular feedback also keeps parents informed about their child's progress and behavior, enabling timely intervention and problem-solving. This finding aligns with research indicating that effective communication among teachers, students, and parents is essential for academic and social success [99]. Face-to-face communication often faces practical and logistical constraints, making digital feedback systems a valuable alternative [100]. These

systems allow teachers to efficiently provide detailed, personalized feedback [101,102]. Kounin's research on classroom management shows that immediate, clear communication about student behavior can prevent disruptive behavior and foster a positive learning environment [103].

Teachers prefer weekly feedback over daily feedback, balancing the need for timely updates with the risk of overwhelming parents. Weekly feedback is generally sufficient for monitoring student behavior and academic progress, whereas daily feedback is reserved for immediate issues [104–108]. Older teachers particularly favor less frequent notifications, relying more on students' self-reporting and comfort with fewer digital interactions [109]. This preference aligns with studies suggesting that experienced teachers prefer less frequent but more substantial feedback sessions, fostering greater student independence and self-regulation [110,111].

Despite these benefits, there are still areas for improvement. Some teachers struggle to balance the timeliness and quality of feedback, suggesting enhancements for more efficient delivery without sacrificing depth or personalization. Additionally, predefined feedback categories may limit flexibility and prevent teachers from effectively addressing unique or emergent issues.

Research has consistently shown that regular and continuous feedback supports reflective thinking, encouraging learners to integrate and apply new or deepened theoretical knowledge into practice and to plan productively for future learning [109,110]. Immediate feedback benefits inexperienced learners by offering prompt guidance, whereas delayed feedback allows for deeper reflection and understanding [41,111,112]. This dual approach promotes metacognitive skills, enabling students to critically evaluate their learning processes and outcomes [7,35]. In digital environments, the immediacy and accessibility of feedback can significantly enhance learning experiences. TEF systems, such as the "Compliments and Comments Tool", streamline the feedback process and ensure that feedback is detailed and specific, which is crucial for effective student learning [10,12]. These systems also improve parental engagement by providing a transparent view of student progress and areas needing improvement, which are strongly associated with improved academic outcomes [14–16].

In conclusion, teachers highly value feedback due to its substantial impact on students' academic success and personal development. Feedback has become a focus of teaching research and practice, as suggested by a recent study by Wisniewski et al. [8]. Continuous and regular feedback supports reflective thinking, learning integration, and productive planning. While face-to-face communication is crucial, online feedback platforms offer convenience, instant communication, and opportunities for teachers, students, and parents to remain informed and involved. Effective feedback and communication are vital for classroom management and addressing student behavior. Balancing immediate and delayed feedback is important depending on the context and student needs. Teachers' investment in providing feedback underscores its significance, and systemic solutions can help optimize the process while considering teachers' workloads and stakeholders' needs.

5.2. Usability of the Feedback Provision Compliments and Comments Tool

The perceived usefulness of the system reflects a user's belief that using the technology will help them improve their work performance [113]. Therefore, the usability of the "Compliments and Comments Tool" is a critical aspect of its effectiveness and overall acceptance by teachers. Our study revealed that the tool is generally well received, with teachers appreciating its ease of use and the structured approach it provides for delivering feedback. The tool's user interface was rated positively, with a significant number of teachers agreeing that it helps them perform their tasks more efficiently, gives them a better overview of classroom activities, and enables them to provide feedback to their students and parents, making it usable according to usability measure instruments [79,82] and user-friendly [94].

However, some areas require improvement to further enhance the usability of the tool. Teachers pointed out that, while the tool is easy to use, it lacks flexibility. While useful, predefined categories do not always allow for the customization required to address unique classroom situations or individual student needs effectively. This rigidity can limit the tool's effectiveness in providing personalized feedback, which is a critical component in fostering student self-regulation and learning [3,38,101]. Additionally, some teachers indicated that the tool could benefit from a more intuitive interface and better integration with other educational technologies to further streamline the feedback process [114–116].

User satisfaction with the tool's effectiveness was high, with many teachers acknowledging its role in enhancing their efficiency, providing a comprehensive view of classroom dynamics and enabling them to provide feedback to their students and parents. These aspects are crucial for fostering an environment where students can receive immediate feedback, which is essential for their growth and development, and aligns with constructivist and cognitive learning theories that emphasize timely and personalized feedback as critical to student learning [4,5]. However, the tool's ability to save time was met with mixed reviews. While some teachers found it time-saving, others felt that the process of entering feedback could be streamlined further, suggesting that the system's usability might be improved by reducing the number of steps required to make an entry and enhancing user flexibility, as suggested by SUS and TAM measure instruments [80–82].

The tool's ease of learning was also positively rated, with most teachers agreeing that they could quickly learn to use it and remember how to use it without requiring extensive written instructions [79,88]. This suggests that the tool is accessible to a broad range of users, including those who may not be technologically proficient. However, the feedback indicated a need for ongoing professional development to help teachers fully utilize the tool's capabilities and ensure that it meets their needs effectively [91].

In conclusion, while the "Compliments and Comments Tool" is generally effective and user-friendly, there is room for improvement. Enhancements that allow for greater customization and flexibility as well as more intuitive design elements could significantly increase its usability and effectiveness. Future iterations of the tool should focus on these areas to better support teachers in delivering high-quality personalized feedback that fosters student self-regulation and academic success.

5.3. Interpretation of the Statistically Significant Differences

The analysis of statistically significant differences in perceptions of the "Compliments and Comments Tool" among teachers reveals critical insights into how various demographic groups interact with the tool. Age significantly influenced the teachers' satisfaction with the tool's usability and effectiveness. Conversely, there were no significant differences in the tool's perceived effectiveness and ease of use between the primary and secondary school teachers.

Teachers aged 31–40 and 41–50 generally found the tool more effective in enhancing efficiency, providing classroom oversight, and saving time than their younger and older counterparts. This could be due to these age groups' balanced experiences with both traditional and digital feedback methods, enabling them to leverage the tool's functionalities effectively [98,117]. Conversely, teachers aged 51 years and older reported lower satisfaction with the tool's ease of use, indicating a greater need for written instructions and support. This suggests that while the tool is generally accessible, older teachers might require additional training and resources to effectively utilize it [117,118]. Interestingly, younger teachers (20–30 years) found the tool easy to use without written instructions but were less satisfied with its overall effectiveness. This discrepancy might reflect a gap between younger teachers' digital proficiency and their pedagogical experience, highlighting the need for professional development that addresses both technological and instructional competencies [119–121]. On the other hand, we found no significant differences in the perceived effectiveness and ease of use of the tool between primary and secondary school teachers. This suggests that the tool's design is broadly applicable across different edu-

cational levels, indicating its versatility. However, the lack of differentiation might imply that the tool does not fully address the unique needs of primary and secondary education settings, which could be an area for future improvement.

In conclusion, the statistically significant differences in perceptions of the “Compliments and Comments Tool” underscore the importance of tailored support and training for different user groups. Ensuring that the tool meets the diverse needs of all teachers, regardless of their age or educational level, is crucial for its widespread adoption and effectiveness. Future research should focus on developing more nuanced training programs and tool enhancements that consider these demographic differences, ultimately leading to a more inclusive and effective TEF system.

6. Conclusions

This study provides valuable insights into the usability and effectiveness of the “Compliments and Comments Tool” for supporting student monitoring and feedback practices. Teachers generally received the tool well, appreciating its user-friendly interface and its potential to enhance feedback to students and parents. The tool facilitates student monitoring and promotes self-regulation through timely and personalized feedback, leading to higher motivation and better academic performance [122–124]. Educators should use tools that support students in setting learning and behavioral goals, self-monitoring, and self-reflection. Research has shown that self-regulated learning and behavior intervention programs significantly impact students’ academic performance, self-regulated strategies, and motivational beliefs [125–127].

Although the tool’s usability is satisfactory, there is room for improvement through content updates and customization to better meet diverse needs. Teachers’ competencies in using technology significantly impact their attitudes towards it [128–131], with positive attitudes enhancing adoption [132,133] and negative attitudes such as fear and risk aversion hindering it [134,135]. Statistically significant differences in perceived usability among different age groups suggest the need for tailored support and training. Younger teachers found the tool easy to use without written instructions but were less satisfied with its overall effectiveness. Older teachers reported lower satisfaction with the tool’s ease of use and required more written instructions and support.

The positive reception of this tool has several practical implications. It enhances teacher efficiency by streamlining the feedback process, facilitates better communication between teachers and parents, promotes self-regulation, and aligns with best practices in educational psychology. To maximize the potential of the tool, ongoing training and professional development for teachers should be prioritized, focusing on effective feedback and technology utilization. Policymakers should support the integration of technology-enhanced feedback systems by providing the necessary resources and infrastructure to ensure equitable access across all schools.

The positive reception of this tool has several practical implications. It enhances teacher efficiency by streamlining the feedback process, facilitating better communication between teachers and parents, promoting self-regulation, and aligning with best practices in educational psychology. Schools should integrate these tools to support holistic student development.

This study has several limitations that must be addressed. Further refinements in customization options and flexibility are required to meet diverse needs. While validity assessments support the use of the questionnaire in measuring teachers’ satisfaction, further research should explore other aspects of validity and the long-term impact of the tool on student outcomes. Another limitation was the questionnaire used to measure usability. Further studies are needed to investigate the relationships between participants’ personality traits and usability outcomes, as well as their attitudes toward technology and cultural and economic factors.

This study establishes a foundation and suggests potential directions for future research. Future studies should explore customizing the tool to meet diverse needs, conduct

longitudinal studies to assess long-term impacts, and compare the effectiveness of the tool with other feedback systems. Integrating artificial intelligence for more personalized feedback and reducing teachers' workloads is a promising area for future development. The "Compliments and Comments Tool" represents a significant advancement in educational technology, offering a user-friendly and effective means for teachers to provide feedback. Emphasizing user-centered design and system usability, the tool has the potential to significantly enhance educational practices and outcomes. Ongoing research and development are essential to refine the tool and ensure it meets the evolving needs of educators and students.

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Article

Teacher Education: Design Thinking Approach in Makerspaces to Produce Quality Educational Video Games with a Visual Identity and Improve Design Thinking Skills

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Abstract: Video games participate effectively in the educational process due to their attractive visual features, but there are many challenges that teachers face when using them. Among these challenges is designing games to suit the goals of the educational process and respecting societal identity. Although there are many studies on educational video games, limited approaches that enhance teachers' education have been explored. The current study focuses on stimulating pre-service teachers' design thinking skills and improving the quality of their video games that have a visual identity by incorporating a design thinking approach into a makerspace. This study followed a quasi-experimental approach, in which 38 pre-service teachers from the departments of Art Education, Early Childhood Education, and Educational Technology at the College of Education at King Faisal University in Saudi Arabia participated. They designed and produced educational video games that consider visual identity and completed the design thinking scale. The results showed that there was great cooperation between participants from all disciplines in the work team, which affected the generation of creative and innovative ideas and the quality of the educational video games. This is due to the use of design thinking elements such as empathy, identification, ideation, and prototyping with different tools in the makerspace. This study calls for the use of a design thinking approach in the classroom learning space for teachers' education, discusses implications for educational practices, and recommends further research in this area.

Keywords: teacher education; design thinking; makerspace; educational video games; visual identity; product quality; Saudi Arabia

1. Introduction

In the current digital age, video games have become increasingly popular, attracting a large number of users. One reason for their popularity is the presence of distinctive characters (cartoon or realistic) [1,2], attractive graphic design, colors [3], and stunning visual effects [4], among other visually appealing elements. In a virtual setting, such visually appealing elements work together to enhance the immersive gaming experience and attract players to the virtual world [5]. Video games have diversified in terms of their content. Entertainment video games provide players with fun, excitement, and thrills [6], while cultural video games offer an opportunity to explore different cultures and traditions [7], and educational video games provide a platform for interactive learning [8]. The integration of video games in education plays an important role as it offers a fun and engaging way for students to learn.

However, there are some challenges that arise when using video games in an educational context. One of these challenges is that many teachers resort to using entertainment or cultural games in their curriculum [9], even though these games may not necessarily meet the educational objectives. While such games can be enjoyable and provide cultural

insights and Wolf [10] emphasizes that video games have become an integral part of popular culture and are integrated into daily life, they may not align with the educational goals. Similarly, Keogh [11] agrees that video game production is not only within the scope of cultural activities but also plays an important role in shaping societal identities. Societal identity can be defined as the factors encompassing culture, the degree of societal advancement, and individuals' connection to it [7] and is formed through cultural norms, traditions, and values [12].

Jaouen and Robin [13], and Vassileva and Penchev [14] agree that there is difficulty in providing educational video games that align with the lesson's objectives and subject matter, or connecting the game's content to the curriculum, which should be determined and designed by the teacher. Furthermore, Vangsnes et al. [15] illustrate that there is a mismatch in education between learning from entertainment games and the learning objectives that a pre-service teacher needs to master. R  th and Kaspar [16] point out that teachers are forced to use commercial video games, even though they are not designed for learning, and they do not align significantly with the lesson objectives. However, they may serve as an alternative to provide opportunities for students to reflect on their gaming experiences and curriculum topics. Alqurashi and Williams [17] believe that some teachers face the problem of commercially designed video games presented in the classroom not aligning with lesson's intended objectives and not supporting the desired educational outcomes accordingly.

Despite the fact that nowadays, teachers' proficiency in designing and using technology (including video games) plays a crucial role in the learning process and innovative teaching practices [18], such a task could be complex and requires advanced knowledge and skills including programming and production skills [19–21]. S  nchez-Mena et al. [22] mention that a lack of experience and the need for teacher training programs are major obstacles in using educational video games in higher education. Sancar Tokmak [23] found that pre-service teachers faced difficulties in designing educational computer games due to limited technological and design knowledge and experience in game design. Moreover, a study conducted by Artym et al. [24] on pre-service teachers' designing and constructing skills of 'Good Digital Games' found that pre-service teachers, in general, were not familiar with the learning principles that should be incorporated into the design of a good digital game.

To overcome these challenges, Bressler and Annetta [25] suggest that training teachers on designing games can enhance their understanding and familiarity with a design thinking approach. Kefalis et al. [26] recommend considering visual design elements in educational video games. Visual identity in educational video games refers to the use of visual design elements to enhance the learning experience [27].

To support pre-teachers' learning about visual identity design skills in educational video games settings, a well-selected design approach should be used that provides them with enhanced learning experiences and promotes creativity among teachers. The design thinking approach is a process of seeking innovative solutions to complex problems through three processes: inspiration, ideation, and implementation [28]. Akhil et al. [29] explain that a design thinking approach involves a team of different specialties working together to develop products that solve problems by combining different perspectives and achieving a better understanding. According to Tsai et al. [30], design thinking helps increase learning motivation and problem-solving abilities, allowing designers to create engaging and effective educational experiences that meet the needs and preferences of students. This approach fosters innovation, collaboration, and user-centered design [31].

Spaces for making, as defined by Morado et al. [32], are collaborative environments equipped with tools, resources, and a community of makers that allow participants to solve problems as creators rather than consumers. Galaleldin et al. [33] confirm that makerspaces encourage collaboration and product development for problem-solving among professionals from various disciplines. Kessner et al. [34] assert that makerspaces provide an ideal environment for fostering creativity and innovation in game design. By adopting a design

thinking approach as a core methodology within makerspaces, which combine digital and traditional manual tools in one place, Browder et al. [35], and Becker and Lock [36] affirm that teachers can be creative and open in designing assessments to meet their students' specific learning goals.

Piaget's constructivism [37] and Vygotskian's social constructivism [38] theories can support learning through the design thinking approach and makerspaces [36,39,40]. Piaget's constructivism believes that learners actively construct their own knowledge and understanding through practical experiences and interactions with their environment. The design thinking approach in a makerspace encompasses an active process of ideation, prototyping, and iterative problem-solving that students need to engage in. This aligns with Piaget's belief of a learner's active role in constructing knowledge. Moreover, a makerspace allows learners to build their own understanding and mental models by posing as open-ended, exploratory design challenges, consistent with Piaget's theory of cognitive development. On the other hand, Vygotskian's social constructivism emphasizes the significance of social interactions and the role of more knowledgeable peers in facilitating learning to achieve beyond the zone of proximal development. The design thinking approach fosters problem-solving, creativity, and collaboration. Makerspaces can provide many opportunities for collaborative and interactive learning. It also enables learners to engage with peers and access expert knowledge and support at their own pace.

This paper aims to undertake a practical exploration of integrating the design thinking approach into teacher education to enhance the development of visual identity design in educational video games. The study goal is to equip pre-service teachers with the necessary skills to improve their design thinking skills and to create a quality video game with a visual identity that may enhance students' comprehension of societies, cultures, histories, civilizations, environments, and societal norms and values.

2. Literature Review

2.1. Educational Video Games with a Visual Identity

Educational video games are computer software systems that combine entertainment and educational elements [39]. They have been found to increase learner engagement, participation, and learning outcomes. Research indicates that educational games can improve students' attitudes towards writing, enhance their motivation, and boost their writing skills [40]. Social video games have also been recognized as supportive tools for developing critical thinking skills, which are crucial for applying knowledge in real-life situations [41]. Language video games make language learning more enjoyable and captivating, leading to increased attention and motivation among students [42]. In professional educational activities, educational games have proven effective in developing improvisation and problem-solving abilities [43].

Video games with visual identities can be a powerful tool for conveying messages, representing cultures [11,12], history [7,18], social studies [42], and life skills [23]. Visual identities in video games refer to the use of visual elements such as designs, symbols, and logos to achieve the goals of a particular institution [33]. It serves as a tangible means of expressing and representing identities through a product or image [44]. Visual identity plays a crucial role in enhancing information recognition, understanding, and enjoyment, as well as adapting messages to different cultures and target audiences [45].

Visual identity holds significant importance in educational institutions. The visual dimension of social worlds has become equally important as a written language and narrative, leading to the development of visual research methods in educational research [46]. Academic institutions have implemented various strategies to enhance visual knowledge among students, including instructional scaffolding, activities, assignments, lectures, readings, software, training courses, and research initiatives [46].

Focusing on the visual elements of a game can be a way to enhance visual art education. It is also stated that participation in identity construction is part of the creative process

and serves as a resource in visual arts education [47]. Here are some ways in which visual identity can be integrated into educational games:

1. **Environmental Design in Games:** The environments and virtual backgrounds of the game should be designed in a way that complements the educational content and creates an immersive learning experience. Mohamad Yahaya et al. [48] found that environmental design in online games has a significant impact. Studies have shown that virtual forest games can enhance positive mood and mental health. Mostajeran et al. [49] further explained that environmental design in virtual games can induce positive emotional and physiological effects. They conducted a study with 27 participants to examine the psychological effects of such exposure. The results showed that exposure to virtual nature significantly improved cognitive performance and restoration ability.
2. **Graphic Design and User Interface in Games:** The visual design of the game should reflect the educational theme and enhance player engagement, creating a cohesive visual identity for the game. By using consistent and visually appealing graphic design, Sentana et al. [50] discussed the impact of graphic design in online games and emphasized the importance of attractive visual elements and principles of animation in creating a high-quality game that influences player behavior.
3. **The Use of Visual Elements in Games:** Relevant symbols or visual elements that represent educational concepts or actions should be integrated within the game. Visual aesthetics, including colors and patterns, play a crucial role in shaping the user experience and engagement in online games.
4. **Characters and Avatars in Games:** Developing unique and visually appealing characters or avatars that align with the educational content can enhance the visual identity of the game. These characters can represent teachers, mentors, or even the players themselves. Designing characters that reflect diversity and inclusivity can create a welcoming and relevant experience for players. Allowing players to customize specific visual aspects, such as their character's appearance or the game interface, can enhance engagement and create a sense of ownership [51]. It allows players to personalize the appearance and elements of their avatars, leading to a sense of identification with the character and enhancing player loyalty to the game [52].

The designer, who creates the electronic game, deals with the problems of contemporary life and human situations, given the rapid civilizational developments in society. Therefore, the importance of designing electronic games using effective visual imagery to provide a simple design, create an integrated reality, and have a concise and impactful effect becomes evident [53]. Despite all that, it is important to achieve a balance between educational content and visual elements to maintain learning objectives. By enhancing the visual identity of the educational experience rather than overpowering it, collaboration between graphic designers, educational experts, and game developers can effectively integrate visual identity into educational video games. Because the idea of teachers designing educational video games with a visual identity to support student learning has not been widely adopted, this study will explore this area further.

2.2. Design Thinking Approach in the Makerspace

Design thinking refers to the cognitive skills, thinking abilities, and practices used by designers to solve problems and generate new ideas [54,55]. This is performed through a series of processes that result in a range of solutions, as highlighted by Hatzigianni et al. [56]. Considering the economic, environmental, and social impacts of the designed solutions are fundamental to the design thinking approach, as pointed out by Zainal et al. [55], Cross [57] also highlights the importance of a multidisciplinary team that brings together diverse expertise, encouraging the team to gain a better understanding of the matter at hand, leading to problem-solving and product development.

Koh et al. [58] and Blundell [59] affirm that the design thinking approach places humans at the center with the goal of improving the human environment, and it is the

most effective method to engage teachers in designing new practices. Zainal et al. [55] mention that the design thinking approach is a creative approach for problem-solving and thinking in human-focused professions, particularly in teaching. Blundell [59] reports the importance of using the design thinking approach to enhance teachers' knowledge. Hsu et al. [60] recommend using the design thinking approach to improve teaching, increase students' confidence, enable them to express their ideas, and engage in activities. Henriksen et al. [54] concluded that teachers' use of design thinking approach stages supported their problem-solving approach and recommended integrating the design thinking approach into current curricula, where the design thinking approach can provide a framework for teachers to address practical practice problems and may enhance their problem-solving abilities. Koh et al. [58] recommended education to prioritize the incorporation of the design thinking approach as an essential component, giving significant consideration to the design dimension that encompasses the attributes of human culture and civilization.

The Hasso Plattner Institute of Design at Stanford (D.school) model, which is one of the design thinking models, consists of five fundamental stages [55,61]:

1. **Empathize:** This stage involves understanding the core idea and empathizing with it. It entails researching user needs, consulting experts to learn more about the domain of interest, making observations, and gaining an empathetic understanding of the problem that the product design aims to contribute to solving.
2. **Define:** In this stage, the problem to be solved is identified by organizing the information and refining the details gathered from the empathize stage. The focus is on the problem, and great ideas are generated with a human-centered approach.
3. **Ideate:** This stage involves generating creative solutions to the problem. Various ideation techniques such as brainstorming, mind mapping, and asking questions can be used to stimulate free thinking and explore a wide range of solutions and ideas. This allows for the generation of the highest possible number of ideas.
4. **Prototype:** This stage involves creating and testing solutions and iterating on them. The implementation begins by producing a number of product versions to make the ideas tangible. These prototypes can be shared and tested within the team itself, in other departments, or with a small group of individuals outside the team. They are investigated, and based on user feedback, they are accepted, improved, or rejected. By the end of this stage, a clearer vision is formed of how real users behave, think, and feel when interacting with the final product.
5. **Test:** The prototypes produced in the prototype stage are tested by conducting interviews with users and presenting the product to them. Their interactions and reactions are observed in order to gain a deep understanding of the product and real users as much as possible. This helps improve the final product and put it in its finalized form.

Studies conducted by Sohaib et al. [62] highlighted the importance of integrating the design thinking approach in programming. Tsai and Wang [28] concluded that the design thinking approach is important for students' learning of computer programming as it positively contributes to their self-efficacy in programming. That study recommended integrating the design thinking approach into programming tasks. Zainal et al. [55] affirmed that the design thinking approach is an important integrated educational approach for teaching programming. Henriksen et al. [54] argued that the term "design thinking in education" refers to the notion that design is one of the roles of the teacher. However, when this design occurs in collaborative spaces for problem-solving, where individuals can come together for creativity, innovation, and learning using various tools and techniques; in an ideal environment, it enhances productivity and provides new ways of learning. This concept aligns with the term "makerspace" [36] and suggests that individuals can build their ideas using a diverse range of materials and tools, ranging from low-tech to high-tech. Components can be shaped and transformed into different projects based on each maker's vision [32]. Oliver [63] stated that makerspaces can be defined by several principles, including self-direction based on student interests, supporting play, curiosity,

and creativity, with tolerance for failure and iteration. Encouraging peer collaboration and skill-sharing between experts and beginners is also promoted.

Becker and Lock [36] outlined the steps involved in working within an educational makerspace:

1. Select one or two skills related to students' learning needs to focus on.
2. Engage students in discussions or brainstorming sessions where they can share their interests and experiences.
3. Divide the work purposefully.
4. Start exploring real problems that impact their lives within their community, personal, local, or global events.
5. Document learning evidence such as assessment models and review lists.
6. Encourage students to express the problem in different ways, such as writing it down or creating a teaching scenario, to make their growth visible to themselves and their teacher.
7. Prompt students to think collaboratively to arrive at creative solutions.
8. Use self-assessments to help students identify their strengths.

Hatzigianni et al. [56] affirm that the design thinking approach is a key element of learning in makerspaces, enhancing skills in experimentation and problem-solving. Becker and Lock [36] state that this integration enables users to engage in design, fostering skill development through promoting creativity, collaboration, and problem-solving abilities. Pruneau and Langis [64], and Hawryszkiewicz et al. [65] emphasize that by incorporating design thinking principles, makerspaces can enhance 21st century skills and competencies, including communication, empathy, and abstract thinking. The design thinking approach can be used within makerspaces to develop skills such as computational thinking, problem-solving, creativity, and innovation [66–68]. Makerspaces provide an educational environment where individuals can engage in complex design and manufacturing practices, allowing them to identify problems, build models, learn and apply skills, review ideas, and share new knowledge with others [69]. Hatzigianni et al. [56] recommend using the design thinking approach with makerspaces in schools, where the design activities allow teachers to enhance students' creativity through play and experimentation. Another study by Andersen and Pitkänen [70] propose using makerspaces and design thinking as an approach to develop teachers' professional practice. where it contributes not only to providing participants with the necessary technological competencies but also to fostering collaboration, creativity, and interaction skills. Despite the mentioned importance of the design thinking approach in makerspaces, this approach is not currently widely used for teacher training.

In summary, previous studies have presented perspectives that confirm the integration of ideas when using the design thinking approach in makerspaces. The combination of these approaches may help to form a comprehensive approach to developing various skills and enhancing creativity, innovation, and problem-solving abilities among participants in the educational process. These are important aspects that require further exploration in designing educational video games with visual identity.

2.3. Product Quality

In educational settings, such as learning projects, services, programs, or training programs, the concept of product quality refers to how well a product aligns with specific design and production criteria [71]. In this case, the authors define product quality as the extent to which the educational game created by the student meets standard specifications and has a visual identity. To assess this, a product quality assessment card designed for this purpose is used. Previous research suggests that continuous peer feedback can enhance product quality by providing students with clear and useful evaluations of their performance [71–74]. Additionally, implementing a design thinking approach within a makerspace can improve product quality by reducing individual workloads, saving time, and facilitating the exchange of focused experiences and perspectives among group

members. Some studies indicate that working in a makerspace fosters creativity, innovation, and learning through the use of various tools and techniques, creating an ideal environment for productivity and new ways of learning [54]. However, the existing literature lacks a thorough examination of how the use of a design thinking approach in a makerspace specifically impacts the quality of an educational video game with a visual identity. The present study places significant emphasis on exploring this particular variable.

3. Research Questions

1. What is the impact of using a design thinking approach in makerspaces to design educational video games with a visual identity on the quality of the final product of among pre-service teachers?

2. What is the impact of using a design thinking approach in makerspaces to design educational video games with a visual identity on the development of design thinking skills among pre-service teachers?

4. Hypotheses

1. There are statistically significant differences at the level of 0.05 among the average scores of the control group (pre-service teachers using a traditional design approach) and experimental group (pre-service teachers using a design thinking approach in makerspaces) in the final product quality assessment card of design educational video games with a visual identity in favor of the experimental group.

2. There are statistically significant differences at the level of 0.05 among the average scores of the control group (pre-service teachers using a traditional design approach) and experimental group (pre-service teachers using a design thinking approach in makerspaces) in the design thinking scale in favor of the experimental group.

5. Participants

This research specifically focused on a group of 76 pre-service teachers, aged between 20 and 21 years, from the Departments of Art Education, Early Childhood Education, and Educational Technology. These individuals were enrolled in bachelor's degree programs at the College of Education, King Faisal University, in the Kingdom of Saudi Arabia. Specifically, they were participants in the "Computer Applications in Education" course during the first semester of the academic year 2021/2022. These students were evenly divided into two groups, with each group consisting of 38 students. All students in the three departments had no previous experience in designing educational video games and had no prior knowledge of designing educational video games with a visual identity.

6. Methodology

Because this study explores cause-and-effect relationships in real-world settings [75], it employed a quasi-experimental research methodology. This study investigates the impact of using a design thinking approach in makerspaces (cause) on the development of design educational video games with a visual identity and the levels of design thinking skills (effect) among pre-service teachers.

The control group designed educational video games with a visual identity using a more traditional linear instructional design model. The teacher explained the steps using a lecture-based classes with no further consultation or collaboration with the educators. The students followed the instructions to produce a video game without conducting extensive research about the target audience.

The experimental group designed educational video games with a visual identity using design thinking principles and in a makerspace setting.

7. Data Collection and Analysis

7.1. Product Quality Card

To evaluate the quality of the final product of the educational video games that has a visual identity, a product quality card was created (Figure 1). The card included three main axes, for a total of 21 items that will be evaluated on a five-point Likert scale (novice = 1; emerging = 2; developing = 3; proficient = 4; expert = 5). The scores on the evaluation card ranged from 15 to 75 points. The overall score on the card reflects the quality of the product. The validity of the product evaluation card was assessed by a panel of experts in the field of educational technology. The results indicated some recommendations for rephrasing certain items for further clarification. There was a good consensus on the overall validity of the card. The reliability of the product quality card was calculated from the data collected in the pilot study using a Spearman coefficient of 0.91, indicating extremely high reliability.

Item	Evaluation				
	Expert 5	Proficient 4	Developing 3	Emerging 2	Novice 1
The general Planning of the Video Game					
1. Determine the educational goal of the video game					
2. Determine the target group to which the game will be presented					
3. Select the devices on which the game will run					
4. Determine the type of the game (action / adventure / simulation... etc.)					
5. Determine the possible actions for the player (jumping - running - walking... etc.)					
6. Determine the challenges that the player will face.					
7. Determine the incentives that the player will receive (points / balance / gold coins / lives / power ... etc.)					
The design of the components of the video game					
8. The game contains an introduction that presents the educational steps of the game.					
9. The design of the game environment, in which the character will play, is compatible with the surrounding society.					
10. Determine the rules of the game.					
11. Design the difficulty level of the game to be from easy to difficult.					
12. Design the game control interface including the main menus and game control buttons.					
The design of visual and audio aids					
13. Visual designs of the game match the surrounding community.					
14. Use colors that reflect the surrounding community.					
15. Select an appropriate sound effect for each action.					
16. Design musical background that is inspired by the surrounding environment.					
17. Design a game scenario that explains the events that the player will go through until the end of the game.					
18. Design a number of characters to suit the game levels.					
19. Design the game characters' clothes inspired by the surrounding environment.					
Video game programming					
20. Write the codes for your video game in Scratch.					
21. The video game works properly without errors.					

Figure 1. Product quality card.

7.2. Design Thinking Scale

The Design Thinking Survey was adapted from Tsai's [76] study that developed the design thinking scale (Figure 2). The scale consisted of 16 closed-ended items, including two reverse-scored items. The scale utilized a four-point Likert scale (strongly agree = 4; agree = 3; disagree = 2; strongly disagree = 1). The scale scores ranged from 16 to 64. Five experts in the field of educational technology evaluated the validity of the instrument. The experts recommended rephrasing some items for further clarification. The recommended revisions were made, and the instrument reached its final form.

The reliability of Tsai's [76] original design thinking scale was 0.842. The reliability of the current study's scale was calculated using Cronbach's alpha coefficient, which was found to be 0.90.

Item	Strongly Agree	Agree	Disagree	Strongly Disagree
Reasoning and Reflection				
1. The makerspace helped me think logically				
2. The makerspace helped me look at things from both the positive and negative sides				
3. The makerspace helped me that while making something, I visualize the process and the end results				
4. The makerspace helped me think through the steps of the task.				
5. The makerspace helped me when I have a problem, look carefully at its context.				
6. The makerspace helped me. When I encounter problems, I will think about the causes and effects				
Ideation				
7. The makerspace helped me have a lot of ideas for doing things				
8. The makerspace helped me to have a very rich imagination				
9. My friends often think my ideas are creative				
Collaboration				
10. I enjoy teamwork in the makerspace				
11. The makerspace helped me be open-minded when dealing with things				
12. The makerspace helped me become a patient person				
13. During teamwork in the makerspace, I get along well with my team members				
Execution				
14. The makerspace helped me keep track of my tasks				
15. I rarely finish tasks on time *				
16. I often stop working on a project after finishing it in the middle of the work *				

* Refers to reverse items

Figure 2. Design thinking scale.

8. Experimental Procedure

The 76 graduate students were randomly divided into two groups of 38 students each. An initial meeting was held with both groups to explain the project, which was to design an educational video game to teach kindergarten children, with the game's idea and design stemming from Saudi society's culture, history, and their surrounding environment. The participants were informed about the skills of educational video games, with a visual identity design needed to successfully complete the project. A pre-intervention assessment of both groups' skills was conducted to ensure homogeneity between the two groups.

The control group completed the task of designing an educational video game with a visual identity in the traditional way with no special intervention. The steps of the design and production of the game were explained using lecture-based classes. On the other hand, the experimental group was provided with a makerspace within the classroom where each stage of the design thinking process (empathize, define, ideate, and prototype) was represented in a different color than the other stages. The authors, then, conducted introductory sessions with the experimental group to familiarize them with the makerspace and the tools that were added to the classroom. The participants in the experimental group had to apply the design thinking approach while working in the makerspace using manual materials, as well as some digital materials and electronic devices (Figure 3), including the following:

- Digital tools: computers, smartphones, printers, scanners, internet connection, sound effects software, audio recordings, microphone for sound recording, drawing software, audio recording software, game programming software, QR codes, PowerPoint, YouTube video clips, Scratch website and mobile phone application for designing educational video games, projectors, graphic design tools, and space for storing items.
- Manual tools: ruler, pens, eraser, compass, colored pencils, blocks, whiteboards for collaboration, concept maps, tools for drawing and planning background and character designs, programming blocks, paper for scenario drawing, and whiteboard.

A timeline was used to show the different stages of the design thinking process, and the skills involved in designing the educational video games with visual identity. Each space designated for one of the thinking design processes included activities for visual identity design skills in educational video games. Posters were used to explain the different tools and materials available at each station. Students in the experimental group were allowed to move through the makerspace, working in different stages to complete each stage of the design thinking approach process as follows (Figure 4):

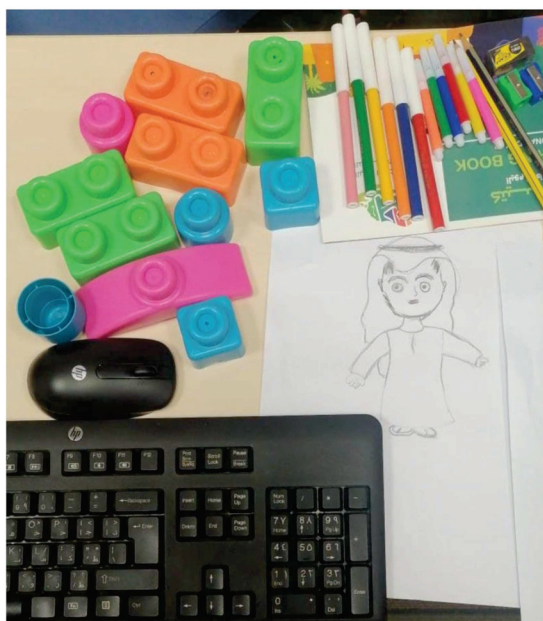


Figure 3. A mix of manual and digital tools used in the makerspace.

1. **Empathize:** In this stage, the basic idea is understood and empathized with. In the makerspace, pre-service teachers from the Department of Educational Technology and the Department of Art Education started by conducting interviews with their fellow pre-service kindergarten teachers. They used a questioning strategy to encourage students to develop their perspectives in order to understand their interests, inquire about their needs, and identify the main topics that need to be designed as educational video games that align with the educational objectives for this age group, as well as with the customs, values, history, and culture of the community. The empathize stage in the makerspace includes using a set of tools such as PowerPoint, YouTube, clipboard, pens, papers, interview guides, and illustrative presentations; sharing video clips and images; presenting ideas that empathize with the problem; and using PowerPoint or videos to demonstrate the idea.
2. **Define:** In this stage, the problem to be solved is identified. The students move to the designated area in the makerspace for the “Define” stage. Pre-service teachers facilitate brainstorming sessions to exchange ideas about a societal problem that aligns with the first objective of the skills of designing an educational video game with visual identity, which is “the overall game concept planning”. One educational objective is selected for each game that suits kindergarten children, and the gameplay is defined. The space is equipped for discussion and idea generation, including tools such as PowerPoint, YouTube, sticky notes, highlighter pens, and whiteboards. The discussions resulted in generating ideas such as the need for games that address specific topics related to the community and its culture, such as learning about currencies, the colors of the flag, and so on.
3. **Ideate:** This stage involves generating creative solutions to the problem. The students move to the designated area in the makerspace for the “Ideate” stage. Pre-service teachers present their initial prototypes of solutions, aligning with the second and third objectives of the skills of designing an educational video game with visual identity, which are “designing the educational game scenario” and “designing visual elements”. The space is equipped with tools such as PowerPoint, YouTube, papers, pens, and colors for writing the game scenario. Additionally, digital tools such as computers and Scratch software are available for designing characters, their outfits, sound effects, and audio. This stage resulted in presenting the game scenario; design-

- ing character and outfit prototypes, backgrounds, control buttons; and incorporating colors that align with the community.
4. **Prototype:** This is the stage of testing and improving solutions. The students moved to the makerspace designated for the “Prototype stage”, which included the fourth objective of the skills of designing an educational video game with a visual identity, which is “programming the game using the Scratch program” (Figure 5). where they create prototypes for designing the game by adding game programming codes, such as sound, control, and movement codes, as well as review the game and modify its elements. The place was equipped with tools for testing and improving solutions, such as plastic cubes to help in learning programming, PowerPoint, YouTube, PDF, electronics tools, computers, and projects, etc. It resulted in the projects being presented and the students testing their prototypes with pre-service kindergarten teachers and making improvements based on their feedback.
 5. **Testing:** Testing involved initial interactions with pre-service kindergarten teachers, discussing all the comments and analytical analyses, monitoring their interaction with the games, and seeking their opinions.

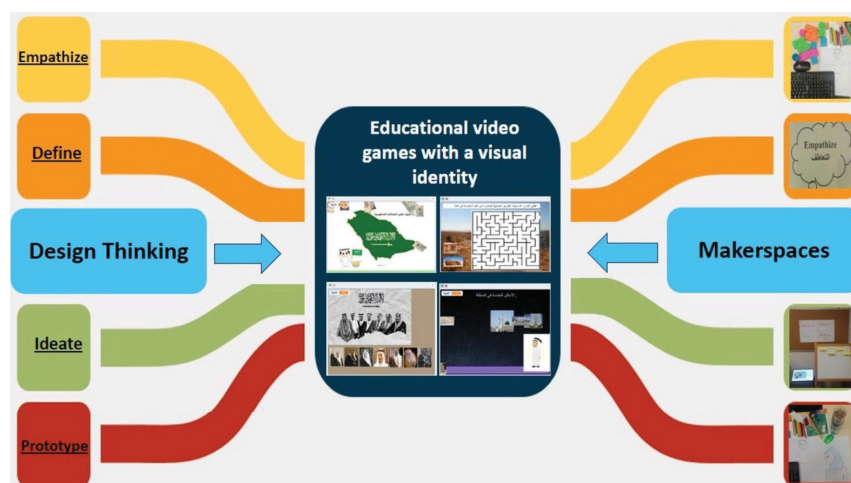


Figure 4. Intervention model.

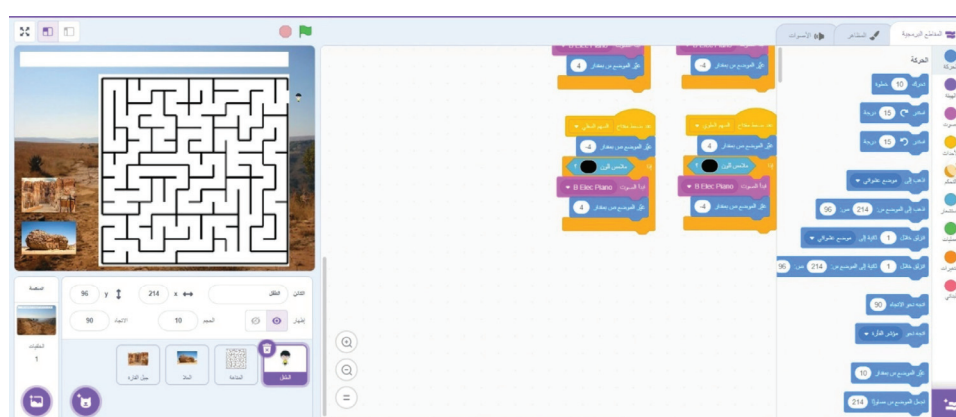


Figure 5. Prototyping a video game to discover Al-Ula’s historical monuments.

Once the experiment had finished, the educational video games with visual identities produced (Figures 6–9) by both the control and the experimental groups were evaluated using the product quality assessment card and the scale of design thinking skills was applied. The data collected from these instruments were processed, analyzed, discussed, and interpreted as follows.



Figure 6. Video game about Saudi Arabian money.

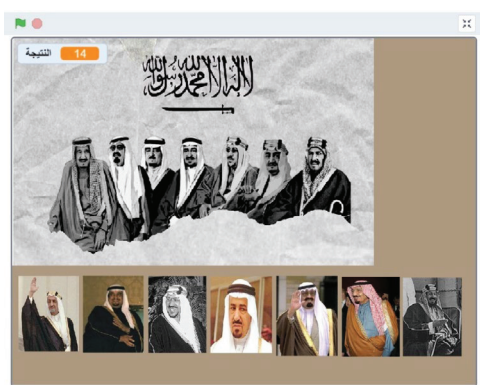


Figure 7. Video game about the kings of Saudi Arabia.

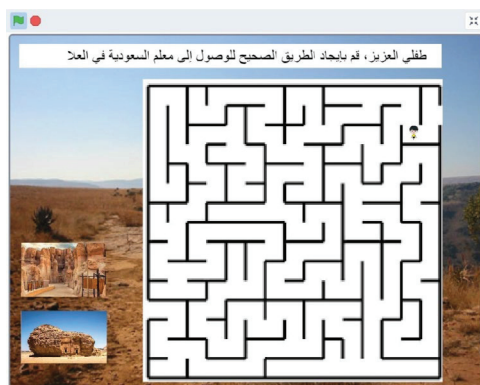


Figure 8. Video game about historical places in Al-Ula.

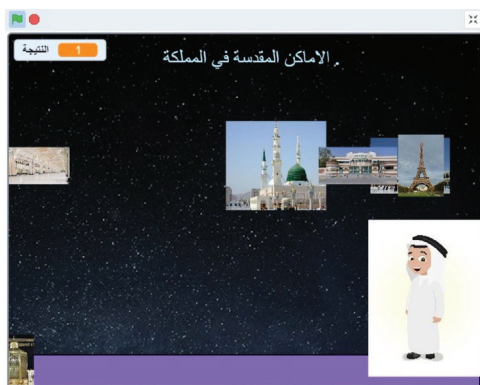


Figure 9. Video game about holy places in Saudi Arabia.

9. Data Analysis and Results

In this study, we identified the impact of using the design thinking approach in a makerspace on developing pre-service teachers' educational video games with visual identities and design thinking skills.

A pre-assessment of design thinking skills was used before implementing the experimental intervention to ensure homogeneity between the experimental and control groups (Table 1).

Table 1. Independent samples *t*-test for pre-intervention design thinking skills.

Group	N	Mean	S.D.	t	df	Sig
Control	38	9.47	3.02	0.074	74	0.942
Experimental	38	9.42	3.21			

As shown in Table 1, the independent *t*-test revealed that there were no significant differences between the experimental and control groups before applying the experiment ($t = 0.074, p > 0.05$). Hence, they were considered homogeneous.

An independent samples *t*-test were also used to determine the significance of differences in the quality of the final product (video game with a visual identity) between the experimental and the control groups. Table 2 shows these results.

Table 2. Independent samples *t*-test for post-intervention product quality.

Group	N	Mean	S.D.	t	df	Sig
Control	38	35.00	10.91	17.61	74	0.000
Experimental	38	69.47	5.17			

As shown in Table 2, there were statistically significant differences ($t = 17.61, p \leq 0.05$) in the mean scores of students between the experimental ($M = 69.47$; $S.D. = 5.17$) and the control ($M = 35.00$; $S.D. = 10.91$) groups in product quality in favor of the experimental group. Therefore, the first hypothesis was accepted.

A design thinking skills assessment (post-assessment) was conducted again once the intervention was completed. Table 3 shows the independent *t*-test for post-intervention assessment for the experimental and control groups.

Table 3. Independent samples *t*-test for post-intervention design thinking skills.

Group	N	Mean	S.D.	t	df	Sig
Control	38	12.21	4.59	34.55	74	0.00
Experimental	38	51.11	5.21			

The *t*-test analysis found statistically significant differences ($t = 34.55, p \leq 0.05$) in the mean scores of students between the experimental ($M = 51.11$; $S.D. = 5.21$) and control ($M = 12.21$; $S.D. = 4.59$) groups on the design thinking skills scale, favoring the experimental group. Thus, the second hypothesis was accepted. This can be attributed to the impact of integrating the design thinking approach in a makerspace on the development of practical design thinking skills.

The findings of this study are in agreement with the studies of Cross [57], Akhil et al. [29], Hatzigianni et al. [56], Becker and Lock [36], Zainal et al. [55], Tsai and Wang [28], Henriksen et al. [54], Sohaib et al. [62], Koh et al. [58], and Fabri [61]. The studies indicate that applying design thinking approach elements such as empathy, definition, ideation, and prototyping with different tools in the makerspace incorporates cognitive abilities, thinking skills, and practices used by designers to address problems and generate new ideas. Assembling a multidisciplinary team with diverse expertise allows the group to

gain a deeper understanding of the issue at hand, facilitating problem-solving and product development. Additionally, when this design process occurs in collaborative workspaces for jointly tackling challenges, where individuals can convene for creativity, innovation, and learning using different tools and methods, it enhances productivity and provides novel ways of learning in an optimal environment. Implementing a design thinking approach in a makerspace saves time and enables the exchange of focused experiences and perspectives among members of the team.

10. Discussion

This research demonstrated the impact of using design thinking in makerspaces on developing pre-service teachers' design skills of educational video games with more emphasis on the visual identity. The integration of the design thinking methodology in a makerspace had an effect on enhancing creativity, fostering practical design skills, and promoting collaboration among pre-service teachers in producing a high-quality video game product. Working in interdisciplinary teams allowed for the exchange of ideas and experiences. Pre-service kindergarten teachers helped clarify the problem they faced in solving kindergarten students' issues, while pre-service art teachers aided in selecting appropriate drawings and images to address the problem. Pre-service educational technology teachers played a role in using computer programs and game programming. The collaboration and assistance among team members significantly improved the creative ideas for solving the visual identity problem in educational video games. Additionally, the enjoyment of the experience positively influenced the participants' intentions to engage in learning.

The diversity of tools available in the makerspace, including both electronic and traditional tools, increased the motivation and enthusiasm of pre-service teachers in utilizing different tools. Colors, drawing papers, and pens greatly facilitated the note-taking during brainstorming sessions and the creation of characters and scenarios, thus stimulating learners' creativity and clarifying their ideas for educational video games design. The use of cubes helped clarify programming concepts using Scratch software, which was used for game programming. PowerPoint presentations and YouTube videos served as complementary electronic tools to traditional tools in the production of the final form of the educational video game with a visual identity.

According to the results, answering the second question, the integration of a design thinking methodology in a makerspace had an impact on the development of pre-service teachers' design thinking skills. The makerspace was divided into four work areas according to the stages of the design thinking process (empathize, define, ideate, and prototype). These areas served as organized steps followed by pre-service teachers in designing the visual identity in educational video games. This allowed them to think freely and in an organized manner in identifying the problem and understanding real-world issues.

The exchange of knowledge and experiences among teachers facilitated the sharing of innovative ideas, discussions, and modifications. Pre-service teachers had the freedom to move within the makerspace between different stages of the design thinking process, which provided flexibility and diversity in their participation without restrictions from the teacher's instructions. This contributed to improving their opinions and facilitated the exchange of creative ideas about the visual identity in educational video games that align with the community, its characteristics, history, civilization, environment, and societal norms and values.

On the other hand, the control group in the study followed a more traditional and linear design process. For example, they relied on assumptions and general knowledge about the target audience (kindergarten children) instead of conducting extensive user research. The control group's design process was sequential and primarily based on the expertise of the design team members, with limited collaboration with educators. They explored fewer alternative solutions and were less inclined to question assumptions or seek innovative ideas. As a result, their designs were less tailored to the specific needs of the

audience and potentially lacked engagement and effectiveness. They also exhibited less innovation and creativity compared to the experimental group.

The integration of a design thinking approach in the makerspace aligns with the principles of Piaget's constructivism and Vygotskian's social constructivism [36–40]. Pre-service teachers should engage in an open-ended process of ideation, prototyping, and iterative problem-solving to learn actively and interactively about the design of video games and visual identity. Applying the design thinking approach within a makerspace has a collaborative nature that promotes social interactions, where learners work together, share ideas, provide feedback, and learn from each other. The presence of instructors and peers in the makerspace setting can offer scaffolding to learners and help them operate within their "zone of proximal development" and advance their understanding and design skills.

11. Conclusions

The analysis and results presented indicate that the use of a design thinking approach in makerspaces can effectively contribute to pre-service teachers' training in the field of educational video games. By combining the concepts of design thinking approach and visual identity design, teachers are able to develop their skills in game design that align with the goals of the educational process while respecting the community's identity. Visual identity is a powerful tool that teachers can use to build a sense of community and identity among students and teachers, while conveying the values of the school and the community and their mission.

This research emphasizes the importance of incorporating elements of the design thinking approach such as empathy, definition, ideation, and prototyping in makerspaces within classrooms to develop teacher education. It indicates that adopting this approach stimulates the participation of pre-service teachers and enhances their creative and innovative thinking. It also generates creative and high-quality ideas for the visual identity of educational video games, leading to improved educational practices and enhancing the learning experience for students in relation to educational video games.

This study can act as a roadmap for those developing educational games with a visual identity and on how to apply the design thinking approach in a makerspace setting. The research can also raise awareness among instructors of technology design courses about the impact of employing the design thinking approach on the quality of student products and improving students' design thinking skills.

This research suggests the need for further research to explore more ways and techniques that promote the use of the design thinking approach in makerspaces for designing educational video games and enhancing teacher education. This requires ongoing collaboration between researchers, teachers, and game developers to develop tools and educational resources that incorporate best practices in this field. It also recommends conducting studies that examine the impact of the design thinking approach in makerspaces on students with different cognitive styles such as ambiguity tolerant/intolerant and field dependence/independence. Researchers can further explore the roles played by individual factors such as age, grade level, and school level status in learning within makerspaces. Future qualitative research is recommended to explore the broader effect of employing a design thinking approach in terms of creativity, cooperation, and working in teams. It highlights the importance of conducting more studies on the design skills of educational video games with a visual identity using different educational technologies, considering its impact on students' learning outcomes.

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Article

Turkish Physical Education Teachers' Use of Technology: Application and Diffusion of Technological Innovations

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Abstract: The purpose of this study was to determine Turkish physical education (PE) teachers' level of technological innovation use and attitudes regarding their applications and diffusion. This study consisted of 678 Turkish PE teachers. In total, 265 (39.1%) of the PE teachers were female, and 413 (60.9%) were male. A sequential explanatory mixed-methods design was used in this study. "The Applying and Diffusing Technological Innovations Scale for Teachers" was used for data collection. The results showed that the main obstacles the PE teachers face in using technological innovations were the cost of products; security and privacy problems; the need for new versions and technical support; the lack of time; the lack of interest; difficulty in accessing technology; and the lack of understanding. Moreover, there was a significant difference in the tendency to apply and diffuse technological innovations in terms of gender, school type, and school level. We found that the "ability to use innovations" sub-dimension affects the PE teachers' tendencies to apply and diffuse technology. As a result, we recommend providing various training programs on technological innovations to the older/longer-serving PE teachers, especially those working in public schools and secondary schools.

Keywords: physical education teacher; technological innovation; diffusion; perception of innovation; individual effects; social effects

1. Introduction

The world is going through very rapid changes, witnessing the beginning of the Fourth Industrial Revolution, and many new concepts have been developed during the last ten years. Artificial intelligence, robots, sensors, and striking developments in internet technologies and digital platforms are bringing the world to the brink of an unprecedented transformation. An incredible quantity of data, robotic systems, 3D printers, and nanotechnology have come into being with the Fourth Industrial Revolution, and they have raised people's living standards. Therefore, in the post-digital world that has begun to be witnessed in the 21st century, information and communication technologies have gained importance in line with the needs of individuals, and economies driven by these technologies have formed. As a result, technologically oriented innovations in social, cultural, political, and economic fields have also affected the education sector and created systemic transformations, including in physical education (PE).

Considering the learning needs of society, as it evolves from the former information society into the digital new world order of the 21st century, rapid access to information any-time and anywhere and instant learning have gained importance. This means that students should be equipped to use, organize, evaluate, present, and communicate information using their new skills. In this process, both the students and the educators who will train them must acquire these skills. For this reason, the level of the ability of educators to use technology should be extremely high, both inside and outside organizations [1]. Although it is generally thought that educators will have certain functions and responsibilities in

providing only information, in reality, educators will have to enter the digital compatibility process with technological changes and development [2]. On the other hand, it is of great importance that educators are aware that technology is now a necessity for human life, as digital technologies have become an inextricable part of almost every aspect of life today, especially for younger people [3].

Due to the rapidly changing and developing technological innovations, the digital tools used in educational environments have increasingly diversified. These tools can be classified as hardware, software, and environments [4]. The examples of hardware include video projectors, smart boards, or interactive boards, as well as mobile hardware tools. This hardware requires software to become functional. The examples of the software group include PowerPoint, Prezi, Excel, Word, Audacity, WeVideo, Adobe Photoshop, Apple iMovie, and Adobe Premiere. For the network group, examples include e-mail systems (Gmail, Yahoo, and Hotmail) for communication; social media, such as Facebook, Twitter, Skype, YouTube, WhatsApp, Messenger, Zoom meetings, and Instagram; search engines, such as Google, Google Maps, and Google Scholar; and blog formats, such as Blogs, Wikis, WordPress, Dropbox, Google Drive, OneDrive, and Cloud-Based Document Storage. These are the modern and traditional hardware infrastructures necessary for the development of technological education methods.

Because students spend most of their time in school, technology can play an important role in better facilitating and encouraging physical activity [5]. Therefore, PE teachers need to integrate technology and diffuse technological innovation to better facilitate and promote physical activity. This study focused on PE teachers' levels of technological innovation use and attitudes regarding applications and diffusion.

1.1. The Diffusion of Innovation (DOI) Theory

The DOI theory developed by Rogers [6] explains how an idea or product gains momentum and how it spreads throughout a certain population or social system. As a result of this spread, people adopt a new idea, behavior, or product as part of a social system. According to Rogers and Singhal [7], diffusion is "the process by which an innovation is transmitted through certain channels over time between members of a social system". Diffusion occurs when an individual perceives an idea, behavior, or product as new or innovative. The main elements are innovations, communication channels, time, and social systems [4,8]. Different roles address different categories when promoting an innovation: innovators, early adopters, early majority, late majority, and laggards [6].

The diffusion of innovation is affected by the social system. Social and contextual influences direct individuals' intention to adopt or maintain innovations [9]. Many individuals are influenced by their peers in deciding whether to adopt an innovation or not. Peers bring new ideas from remote social networks to innovators. These networks provide locally oriented early adopters access to these innovations. Early adopters act as opinion leaders and show the early majority the advantages of innovations. Owing to peer pressure and economic imperative, the late majority and laggards finally adopt innovations [6]. Khanagha et al. [10] stated that diffusion is a gradual process. The adoption and implementation of contemporary technologies in education have been relatively slow [11].

Rogers [6] identified five stages in the innovation process and the conditions that affect the new idea, product, or practice to be adopted: knowledge (exposure and understanding); persuasion (attitude building); decision (commitment to diffusion); application (use); and approval (reinforcement owing to positive results). Therefore, for teachers to adopt innovative technology, they must try to understand it—to receive education, to be convinced that it will work, to decide to use and diffuse it, to start using it, and to confirm that the technology works for them. Factors such as the propensity for technologies, interests, abilities, economic conditions, and time are effective in applying and adopting innovative technologies among teachers. In addition, increased access to digital technology and technical support, appropriate teacher training, and a supply of the necessary equipment

to teachers, students, and the main stakeholders in education are the prerequisites for efficiently adopting technology in education [12].

1.2. Physical Education Teachers' Use of Technology

Recently, many studies have highlighted the significance and prospects of using technology [13]. However, several studies have also highlighted the importance of effective physical practices in technology use and have proposed ideas in this regard [14,15]. There are prospective benefits associated with using technology in promoting physical activity. For example, many scientific studies have been conducted to improve athletes' training and performance [16,17]. These studies pave the way for the production of state-of-the-art tools and systems used in physical education and sports [18]. Particularly with mobile technology, physical educators now have a wide range of tools that they can use to examine and improve their student's physical skills. These tools provide evidence of their positive impact on educational processes; they have supported mobile technology [19], analyzed video tutorials as a teaching tool [20], and showed the impact of video games in physical education [21]. Some studies have also confirmed that technology promotes the development of physical and psychological skills, enhances creativity and personal involvement, and facilitates an individualized pace of learning [22,23]. Physical education teachers need to adapt to these technological developments in the educational environment.

However, some researchers have observed that teacher burnout and resistance to innovation owing to the stress caused by "change" constitute an obstacle to adopting any innovation in education and that mandatorily implementing technology does not lead to high-level adoption [24,25]. At this point, there is a need to understand whether PE teachers have a willingness to apply and diffuse technological innovations. Therefore, the purpose of this study was to understand the current situation regarding Turkish PE teachers' obstacles to using technological innovations and their tendency to apply and diffuse technological innovations.

In this context, our research questions were as follows: Is there any difference in technological innovation use among PE teachers in terms of gender? Is there any difference in the main obstacles faced by PE teachers in using technological innovations in terms of gender? What are the other main obstacles faced by PE teachers in using technological innovations? Is there a difference in the tendency of PE teachers to apply and diffuse technological innovations in terms of school type? Is there a difference in the tendency of PE teachers to apply and diffuse technological innovations in terms of school level? Is there any difference in the tendency of PE teachers to apply and diffuse technological innovations in terms of years of professional service? Do the main obstacles PE teachers face in using technological innovations predict their tendency to apply and diffuse technological innovations?

2. Materials and Methods

2.1. Research Design

This study used a sequential explanatory mixed-methods design to determine the obstacles faced by Turkish PE teachers in using technological innovations and their tendency to apply and diffuse technological innovations. Mixed-methods research is used in the field of health, social, and behavioral sciences, wherein the researcher integrates two sets of data, both quantitative and qualitative, to understand the research problem and then draws conclusions using the advantages of integrating these two sets [26]. The quantitative part of the research was based on the PE teachers' responses to the Applying and Diffusing Technological Innovations Scale for Teachers, and the qualitative part of the research consisted of responses to a question regarding what other obstacles the PE teachers face when using technological innovations.

2.2. Participants and Procedures

The participants were PE teachers working in different regions and provinces during the 2019–2020 spring academic semester in Turkey.

As shown in Table 1, in total, 678 PE teachers voluntarily participated in the study. Of these PE teachers, 265 (39.1%) were female, and 413 (60.9%) were male ($Age_{mean} = 40.50 \pm 5.8$); 315 (45.9%) worked in middle schools, and 363 (54.1%) worked in high schools; 634 (93.9%) worked in state schools; and 44 (6.1%) worked in private schools. Of these PE teachers, 57 (7.1%) had 1–5 years, 168 (22.5%) had 6–10 years, 138 (20.5%) had 11–15 years, 191 (30.2%) had 16–20 years, 124 (9.5%) had 21 years and over of working experience; 577 (90.7%) completed undergraduate education, and 101 (9.3%) completed postgraduate studies.

Table 1. Demographic information of PE teachers.

Variable	Level	Frequency (<i>n</i>)	Percent (%)
Gender	Female	265	39.1
	Male	413	60.9
School level	Middle	315	45.9
	High	363	54.1
School type	State	634	93.9
	Private	44	6.1
Professional service years	1–5 years	57	7.1
	6–10 years	168	22.5
	11–15 years	138	20.5
	16–20 years	191	30.2
	21 years and over	124	19.5
Education	Undergraduate	577	90.7
	Postgraduate	101	9.3

The PE teachers were recruited through an explicit sampling procedure [27]. This was convenience sampling, in that any PE teacher who fit the inclusion criteria was included. The university institutional review board approved the study before implementation. The researchers sent an online questionnaire to the PE teachers who wanted to participate via e-mail and social media. In addition to the questionnaire, information was provided about the purpose of the study, the inclusion criteria (working as a PE teacher in a state school), and the participants' right to withdraw with a consent form before data collection. The PE teachers who met the inclusion criteria completed the questionnaire, which included 18 items and an open-ended question. Finally, the data were transferred to the SPSS statistics software package (SPSS 26.0 version).

2.3. Measurement

The tendency of the PE teachers to apply and diffuse technological innovations was evaluated using “The Applying and Diffusing Technological Innovations Scale for Teachers” (ADTI-S). Savery [28] developed a 32-item scale, with 10 multiple-choice questions and 22 4-point Likert-type items. Savery used the roles in the diffusion of innovation (DOI) theory developed by Rogers [6] in developing this survey. Many of the words used by Rogers [6] in the definitions of innovation characterizations (for example, bold, willing, suspicious, and resilient) were included in the survey.

In this study, 21 items used by Savery [28] and 5 items prepared by the researchers were combined. A total of 26 items were formed, and the items were arranged according to the teachers. The scale was a 5-point Likert type and was applied to 468 Turkish PE teachers. As a result of the exploratory factor analysis ($n = 268$), 18 items were obtained. The scale

had four sub-dimensions: individual effects (items 1, 2, 3, 4, 5, 6, and 7), perceptions about innovations (items 8, 9, and 10), social effects (items 11, 12, and 13), and ability to use innovations (items 14, 15, 16, 17, and 18).

As a result of the confirmatory factor analysis ($n = 200$), the fit values of $\chi^2 = 385.17$, degrees of freedom (df) = 129, $n = 200$, root mean squared error of approximation (RMSEA) = 0.10, standardized root mean square residual (SRMR) = 0.08, comparative fit index (CFI) = 0.93, normed fit index (NFI) = 0.89, non-normed fit index (NNFI) = 0.91, and goodness of fit index (GFI) = 0.82 were found to be at the level of good or perfection [29]. Internal consistency coefficients were calculated to determine the scale's reliability. The total Cronbach Alpha coefficient of the four sub-dimensions of the scale was 0.80, that of the first sub-dimension was 0.70, that of the second sub-dimension was 0.73, that of the third sub-dimension was 0.80, and that of the fourth sub-dimension was 0.71. In addition, an open-ended question asked the PE teachers to provide their own opinions regarding the other obstacles they face when using technological innovations.

2.4. Data Analysis

The histogram and distribution charts were examined before using parametric tests in this study. We observed that the curve showed a symmetrical distribution, and the Skewness–Kurtosis values were between -1.5 and $+1.5$ [30]. Additionally, the homogeneity of the sample was examined with the Levene test according to the school type, school level, and years of professional service, and the p -value was found to be higher than 0.05. Descriptive statistics were used for demographic variables. Chi-square analysis was used to compare the PE teachers' use of technological innovations according to gender. Chi-square analysis was used to determine what the main obstacles faced by the PE teachers in using technological innovations were according to gender. Additionally, a t -test was used for independent groups to compare the PE teachers' tendencies to apply and diffuse innovative technologies according to school type and school grade variables. Moreover, Analysis of Variance (ANOVA) was used for independent groups to compare the PE teachers' tendency to apply and diffuse innovative technologies according to the professional service year variable, and Tukey's range test was used to determine which groups the difference was between. Finally, multiple linear regression analysis was used to predict whether the main obstacles faced by the PE teachers in using technological innovations predicted their tendency to apply and diffuse them.

In addition, to support quantitative design, inductive content analysis was used for the PE teachers' responses to the open-ended question. The researchers used inductive content analysis and constant comparison [31] to identify the initial categories and emergent themes from the data [27]. Initial categories were discussed among the researchers to explore the similarities and differences between the groups until an agreement about the coding protocol was established and verified. The second cycle of coding employed a thematic analysis. For the inductive content analysis, data coding, theme identification, data organization according to theme codes, and the interpretation of the findings followed. The qualitative data set was coded as "PET 1, PET 2, and PET 3...", where PET 1 means PE teacher 1. Six-page-long answers were obtained from the open-ended question, and 163 coded units were obtained. As a measure of reliability, the consensus between the two researchers was calculated by consensus, as suggested by Miles et al. [32]. The data from the open-ended question were obtained with an 86% consensus.

3. Results

This section includes findings about the Turkish PE teachers' obstacles in using technological innovations and their tendency to apply and diffuse them in terms of gender, school type, school level, and years of professional service.

Table 2 shows that 93.5% of the PE teachers who participated in the study stated that they have accounts such as Facebook, Instagram, and Twitter, and 6.5% did not. No significant difference was found in the comparison according to gender ($\chi^2_{(1)} = 0.004^a$;

$p = 0.542$). In total, 93.5% of the PE teachers stated that they have a laptop, tablet, or computer, and 7.5% did not. No significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 1.378^a$; $p = 0.153$). In total, 29.2% of the PE teachers stated that they had a personal web account, and 70.8% did not. No significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 1.223^a$; $p = 0.154$). In total, 8.4% of the PE teachers stated that they had a personal blog, and 91.6% did not. No significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 0.132^a$; $p = 0.416$). In total, 26.1% of the PE teachers stated that they had a Skype account, and 73.9% did not. No significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 0.255^a$; $p = 0.338$). In total, 99.4% of the PE teachers stated that they had a WhatsApp account, and 0.6% did not. In brief, a significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 6.271^a$; $p = 0.023$). In total, 97.8% of the PE teachers stated that they had an e-mail account that they actively used, and 2.2% did not. A significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 4.901^a$; $p = 0.027$).

Table 2. PE teachers' use of technological innovations in terms of gender.

	Variable	Female	Male	Total	Sd	χ^2	p
Has accounts such as Facebook, Instagram, and Twitter	Yes	248 (36.6%)	386 (56.9%)	634 (93.5%)	1	0.004	0.542
	No	17 (38.6%)	27 (61.4%)	44 (6.5%)			
Has a laptop, tablet, or computer	Yes	249 (36.7%)	378 (55.8%)	627 (93.5%)	1	1.378	0.153
	No	16 (2.4%)	35 (5.1%)	51 (7.5%)			
Has a personal web account	Yes	71 (10.5%)	127 (18.7%)	198 (29.2%)	1	1.223	0.154
	No	194 (28.6%)	286 (42.2%)	480 (70.8%)			
Has a personal blog	Yes	21 (3.1%)	36 (5.3%)	57 (8.4%)	1	0.132	0.416
	No	244 (36.0%)	377 (55.6%)	621 (91.6%)			
Has a Skype account	Yes	72 (10.6%)	105 (15.5%)	177 (26.1%)	1	0.255	0.338
	No	193 (28.5%)	308 (44.5%)	501 (73.9%)			
Has a WhatsApp account	Yes	261 (38.5%)	413 (60.9%)	674 (99.4%)	1	6.271	0.023 *
	No	4 (1.5%)	0 (0%)	4 (0.6%)			
Has an actively used mail account	Yes	255 (37.6%)	408 (60.2%)	663 (97.8%)	1	4.901	0.027 *
	No	10 (1.5%)	5 (0.7%)	15 (2.2%)			

* $p < 0.05$; χ^2 = chi-square; Sd = standard deviation.

Table 3 shows that in terms of the main obstacles encountered in using technological innovations, 32.4% (n: 220) of the teachers stated that the technology was expensive; 19% (n: 129) stated that there were security problems; 9.6% (n: 65) stated that there were privacy problems; 15.0% (n: 102) stated that there was a need to follow new versions; 15.6% (n: 106) stated that there was a need for technical support; 0.9% (n: 6) stated that they were under stress; and 7.4% (n: 50) stated that training was necessary to learn. A significant difference was found in the comparison in terms of gender ($\chi^2_{(1)} = 0.27.882$; $p = 0.000$).

Table 3. The main obstacles faced by PE teachers in using technological innovations in terms of gender.

	Variables	Female	Male	Total	Sd	χ^2	p
The main obstacles faced by the PE teachers in using technological innovations	Expensive	83 (12.2%)	137 (20.2%)	220 (32.4%)	6	27.882	0.000 *
	Security problems	45 (6.6%)	84 (12.4%)	129 (19%)			
	Privacy problems	15 (2.2%)	50 (7.4%)	65 (9.6%)			
	Need to follow new releases	58 (8.6%)	44 (6.5%)	102 (15.0%)			
	Need for technical support	37 (5.5%)	69 (10.2%)	106 (15.6%)			
	Being under stress	5 (0.7%)	1 (0.1%)	6 (0.9%)			
	Need for training to learn	22 (3.2%)	28 (4.1%)	50 (7.4%)			

* $p < 0.05$; χ^2 = chi-square; Sd = standard deviation.

Additionally, the PE teachers were also asked what other obstacles they faced in using technological innovations, and a content analysis of their answers is provided below. One of the obstacles faced by the PE teachers in using technological innovations was defined as a “time problem” ($n = 132, 38\%$). For example, PETs 5 and 139 stated, “Time is needed to get to know and use technology”; PET 422 stated, “There is no time to use the technology from bickering with real life, I also think it is not a good idea to be embedded in electronic devices. Moreover, even the daily hustle and bustle prevent us from seeing and noticing what is happening around us, the sky, the sea, the tree, and the people”.

Another obstacle expressed by the PE teachers is a “lack of interest in technology” ($n = 74; 21.3\%$). For example, PET 49 stated, “My students’ indifference to technology distracts me from technology too”; PET 556 stated, “I do not see it necessary, I only learn what I need”; PET 173 stated, “There are many people who think it is necessary”; PET 342 stated, “I do not like technology, I think I am a little disabled”; PET 104 stated, “I do not need much technology”; and PET 285 stated, “I am far from technology”.

Moreover, the PE teachers stated that another obstacle is “difficulty in accessing technology” ($n = 38, 11\%$). For example, PET 98 stated, “Unfortunately, everyone cannot reach technologies”; PET 166 stated, “I cannot find every technology in Turkey”; PETs 345 and 542 stated, “I think it is limited domestic production”; PET 612 stated, “Technology changes rapidly, we do not keep up with the changes, and we cannot reach”; PET 428 stated, “We are not aware of new technologies”; and PET 650 stated, “I cannot use new technologies because they are not supported by the institution”.

Finally, the PE teachers stated that another obstacle is the “lack of understanding of its use” ($n = 103, 29.7\%$). For example, PET 51 stated, “I find the technology too complicated”; PET 513 stated, “I do not understand because my foreign language is not good”; PET 379 stated, “I am confused by a wide variety of technologies”; PET 113 stated, “I think the introduction of some technologies is inadequate, which makes it difficult for me to understand”; PET 274 stated, “They are not explanatory enough”; and PET 467 stated, “Their usage is not clear”.

Table 4 shows that there is a significant difference in the sub-dimensions of individual effects and the ability to use innovations sub-dimensions regarding the tendency of the PE teachers to apply and diffuse technological innovations in terms of school type ($p < 0.05$). This difference was in favor of private schools in terms of individual effects ($M = 27.34 \pm 3.402$) and the ability to use innovations ($M = 19.54 \pm 2.444$). Furthermore, the data indicated that there is a significant difference in the social effects and ability to use innovations sub-dimensions regarding the tendency of the PE teachers to apply and diffuse technological innovations in terms of school level ($p < 0.05$). This difference was in favor of high schools in terms of social effects ($M = 11.02 \pm 2.320$) and the ability to use innovations ($M = 18.40 \pm 3.823$).

Table 5 shows that there is a significant difference in the individual effects [$F(4,673) = 3.758, p < 0.05$], perceptions about innovations [$F(4,673) = 4.188, p < 0.05$], and ability to use innovations [$F(4,673) = 5.340, p < 0.05$] sub-dimensions regarding the tendency of the PE teachers to apply and diffuse technological innovations in terms of years of professional service ($p < 0.05$).

Table 6 shows that the prediction equation for the main barriers faced by the PE teachers in using technological innovations regarding their tendency to apply and diffuse technological innovations was significant ($R^2 = 0.028, F = 4.856, p < 0.05$). Analyzing the significance of the regression coefficients showed that the ability to use innovations sub-dimension is a significant predictor of the main barriers the PE teachers face in using technological innovations. In summary, the individual effects, perceptions about innovations, and social effects sub-dimensions were not the significant predictors of the main barriers the PE teachers face in using technological innovations.

Table 4. Comparison of PE teachers' tendencies to apply and diffuse technological innovations in terms of school-type and school-level variables.

Sub-Dimension	School Type	n	$\bar{X}$	Sd	t	p
Individual effects	State	634	25.87	4.462	−2.135	0.033 *
	Private	44	27.34	3.402		
Perceptions about innovations	State	634	11.67	1.688	−0.205	0.838
	Private	44	11.72	1.619		
Social effects	State	634	10.74	2.216	−1.669	0.096
	Private	44	11.31	2.031		
Ability to use innovations	State	634	17.95	3.935	−2.640	0.008 *
	Private	44	19.54	2.444		
Sub-dimension	School level	n	$\bar{X}$	Sd	t	p
Individual effects	Middle school	315	25.87	3.932	−0.535	0.593
	High school	363	26.05	4.797		
Perceptions about innovations	Middle school	315	11.61	1.703	−0.926	0.355
	High school	363	11.73	1.666		
Social effects	Middle school	315	10.49	2.036	−3.133	0.002 *
	High school	363	11.02	2.320		
Ability to use innovations	Middle school	315	17.66	3.902	−2.474	0.014 *
	High school	363	18.40	3.823		

* $p < 0.05$; $\bar{X}$ = arithmetic mean; Sd = standard deviation.

Table 5. Comparison of PE teachers' tendencies to apply and diffuse technological innovations in terms of years of professional service.

Sub-Dimension	Professional Service Years	n	$\bar{X}$	Sd	df	F	p	Tukey
Individual effects	1–5 years	57	27.54	4.145	4 673 677	3.758	0.005 *	1–5 > 21 years and over
	6–10 years	168	26.31	3.930				
	11–15 years	138	26.21	5.068				
	16–20 years	191	25.57	4.114				
	21 years and over	124	25.12	4.621				
Perceptions about innovations	1–5 years	57	12.38	1.130	4 673 677	4.188	0.002 *	1–5 > 16–20
	6–10 years	168	11.68	1.854				
	11–15 years	138	11.45	1.040				
	16–20 years	191	11.79	1.791				
	21 years and over	124	11.41	1.950				
Ability to use innovations	1–5 years	57	19.03	4.122	4 673 677	5.340	0.000 *	1–5 > 21 years and over
	6–10 years	168	18.58	4.390				
	11–15 years	138	17.94	2.673				
	16–20 years	191	18.23	4.358				
	21 years and over	124	16.77	2.979				

* $p < 0.05$; $\bar{X}$ = arithmetic mean; Sd = standard deviation; df = degree of freedom; F = variance.

Table 6. Level of prediction of the main obstacles faced by PE teachers in using technological innovations regarding their tendency to apply and diffuse technological innovations.

Sub-Dimensions	β	Standard Error	B	t	p
Constant	4.355	0.555		7.850	0.000
Individual effects	−0.012	0.021	−0.029	−0.572	0.568
Perceptions about innovations	0.051	0.050	0.046	1.008	0.314
Social effects	−0.040	0.038	−0.047	−1.052	0.293
Ability to use innovations	−0.070	0.023	−0.143	−3.038	0.002 *
	R = 0.167	R ² = 0.028	F = 4.856	p = 0.000 *	

* $p < 0.05$; β = beta; B = a “unit-free” standardized coefficient.

4. Discussion

This study provided information about Turkish PE teachers’ use of technological innovations in terms of gender and the main obstacles they face in using technological innovations (trends in applying and diffusing technological innovations in terms of professional service years, school type, and school level). In addition, this study determined the effects of the main obstacles faced by the PE teachers in using technological innovations on their tendency to apply and diffuse technological innovations.

First, we examined the PE teachers’ use of technological innovations in terms of gender. Most of the PE teachers included in the research group had accounts such as Facebook, Instagram, and Twitter ($n = 634$). Moreover, they had laptops, tablets, or computers ($n = 627$). In addition, the teachers had WhatsApp accounts ($n = 674$) and stated that they actively used e-mail for communication. ($n = 663$). Therefore, the PE teachers use technological innovations to communicate with others. Furthermore, the data indicated that the PE teachers did not have personal web accounts ($n = 480$), personal blogs ($n = 621$), or Skype accounts ($n = 501$). A significant difference was found in terms of gender regarding having a WhatsApp account and an actively used Gmail account. Additionally, the data indicated that the male PE teachers used WhatsApp and actively used an e-mail account more often. Çuhadar et al. [33] found that pre-service teachers approach technological innovations with skepticism. Therefore, it can be argued that PE teachers adopt some communication tools in terms of gender but others are skeptical.

Second, the PE teachers were asked about the main obstacles they face in using technological innovations in terms of gender. Accordingly, the “expensiveness” of technological innovations (n : 220) was the most important obstacle. Afterwards, security problems (n : 129) and a need for technical support (n : 106) were indicated. Tınmaz and Yakın [34] reported that the main obstacles were the cost of using technological innovations, security problems, privacy issues, and following the new versions of these technologies. On the other hand, Özgür [35] found that the most important factors preventing teachers from using computers in education were an insufficient budget, a lack of hardware, and inadequate in-service training. Gibbone et al. [36] stated that limited budget and a lack of access to appropriate technology are important barriers to PE teachers’ adoption of technology. Moreover, Konukman et al. [37] stated that both female and male PE teachers were concerned about the safety of themselves and their students while using technology for learning.

We found a significant difference between the main obstacles the PE teachers face in using technological innovations in terms of gender. The male PE teachers indicated expensive technology, security, and privacy problems; a need for new versions and technical support; and a need for training as greater barriers to using technological innovations than the female PE teachers. On the other hand, the female PE teachers indicated that being under stress in using technology was a greater barrier than others. Accordingly, despite some issues, the male PE teachers feel more confident and competent in using technological innovations than the female teachers. Similarly, Tınmaz and Yakın [34]

found that male university students were more enthusiastic about following technological innovations. Moreover, Juniu et al. [38] found that male prospective PE teachers were more comfortable using technology, and they had more positive attitudes towards technology use. Conversely, Yilmaz et al. [39] observed that female instructors were more successful in individual innovation than male instructors. Tou et al. [40] found that male PE teachers had more positive attitudes towards using digital technology tools than their female colleagues in areas related to innovative and modern teaching.

Moreover, the PE teachers were asked what other obstacles they faced in using technological innovations in this study. The themes were “the time problem, a lack of interest in technology, difficulty in accessing technology, and a lack of understanding its use”. Furthermore, several of the PE teachers stated that they do not need technology, have no interest, and are not aware of new technology. In addition, these PE teachers stated that they could not keep up with changes, and they had problems owing to language problems or a lack of comprehensibility. In brief, creating enough time to adopt technological innovations in daily life, being interested in technology, and the accessibility and comprehensibility of technology will make it easier for individuals to spread it. Regarding this point, Tinmaz and Yakın [34] stated that time is an obstacle in using technological innovations in general. Hsua et al. [41] found that the characteristics of being useful, compatible, and observable are the most important factors in innovation adoption. In their theoretical analysis, Maksimovic and Lazic [42] pointed out the need for expanding and developing the digital competencies of physical education teachers. Therefore, it is important to make technology useful, understandable, and easily accessible for PE teachers to adopt and use its innovations.

We examined whether there was a difference in the PE teachers’ tendencies to apply and diffuse technological innovations in terms of school type. Accordingly, we determined that there was a significant difference in favor of private schools in the “individual effects and ability to use innovations” sub-dimensions. Personal innovativeness, which includes individuals’ willingness to use technological innovations, is one of the key factors for implementing innovation [9]. Corvin [43] stated that technologically innovating schools require enough resources for changes and innovations, and for this, it is important that resources outside the school are well researched and that the school has a large enough workforce to implement freedom and changes.

In the institutionalization policies of private schools, the use of technological innovations for the all-round development of students is at the forefront. In private schools, teachers are encouraged to apply technological innovations up to the highest level and are provided with the necessary training to use them. Therefore, it is expected that the individual effects of the PE teachers working in private schools—such as those due to adopting, following, pioneering, and spreading technological innovations—are more significant than those of the teachers working in public schools. In addition, Loogma et al. [44] found that school management and in-school planning play a major role in increasing educators’ understanding of innovation and developing e-learning techniques. Lope Pihie et al. [45] stated that the concept of innovation and change within a school develops depending on its administrative management and that administrative committees have a significant effect on the adoption of new thoughts and ideas by educators. Thus, the administrative policies of private schools have a positive effect on PE teachers’ tendency to implement and disseminate technological innovations. However, other studies have emphasized that even if a school administration supports the use of technology in public schools, PE teachers do not prefer to implement technological innovations owing to negative technology use bias or a lack of teaching knowledge on how to use technology in physical education [46].

Furthermore, this study examined whether there is a difference in the PE teachers’ tendencies to apply and diffuse technological innovations in terms of school level. Accordingly, we determined that there was a significant difference in favor of high schools in the “social effects and ability to use innovations” sub-dimensions. Therefore, the high school PE teachers influence and encourage each other more in applying and diffusing techno-

logical innovations than the secondary school PE teachers. Kösterelioğlu and Demir [47] found that primary and secondary school teachers cooperate with their colleagues in implementing and disseminating technological innovations and are open to others' experiences. In addition, Könings et al. [48] emphasized that educators should constantly collaborate to develop and make sense of individual innovativeness. Van de Ven [49] stated that the idea of innovation occurs through the exchange of ideas and knowledge transfer between individuals in social life. On the other hand, Eren [50] completed a study with university students and found that social effects were important in adopting technological innovations and mass media, and interpersonal relationships were effective in the spread of technological innovation in a population [9]. Therefore, social interaction among PE teachers is important in the adoption and use of technological innovations. However, Tou et al. [40] found no significant difference in attitudes toward technological tool use among PE teachers at different school levels.

In addition, the study examined whether there was any differentiation in terms of the PE teachers' tendencies to apply and diffuse technological innovations with regard to years of professional service. Accordingly, a significant difference was found in favor of the PE teachers with 1–5 years of professional service in the "individual effects, perceptions about innovations, and ability to use innovations" sub-dimensions. Therefore, effects such as using technological innovations more; being curious; and following, adopting, pioneering, and spreading technological innovations were more in favor of the new PE teachers. Therefore, young and new teachers are more curious about applying and diffusing technological innovations. In particular, Baek et al. [51] found that experienced PE teachers with good PE experience did not think technology played an important role, and they believed that technology was an unnecessary tool for good teaching. In brief, research indicates that the PE teachers with less experience are more likely to accept the use of technological tools in physical education, especially in areas related to computer literacy and equipment [52]. However, there is also research that shows the opposite [40,53].

In the final analysis, this study examined whether the main obstacles faced by the PE teachers in using technological innovations predicted their tendency to apply and diffuse technology. In the estimation equation, the "ability to use innovations" sub-dimension was found to be significant. We found that the "individual effects, perceptions about innovations, and social effects" sub-dimensions are not the significant predictors of the main barriers encountered in using technological innovations. According to this analysis, the teachers' ability to use innovations negatively affects their tendency to apply and diffuse technology. Accordingly, the teachers are inadequate in using new technologies, they are not interested in new technologies, and they do not have experience in using new technologies. PE teachers lack experience in using technological innovations in physical education [52] and may not be familiar with different roles in their implementation [54]. In this context, new technologies should be introduced and guided, and in-service training should be provided via official institutions for PE teachers to use and adopt technological innovations.

5. Conclusions

Especially in today's world, a contemporary education system is needed for teachers to keep up with and benefit from innovations. A teacher in a modern education system should not be afraid of innovations and should aim to carry this train of thought to their students. Our results indicate that PE teachers face some obstacles in using technological innovations. Accordingly, it is important to overcome these barriers, such as expensive technology, security problems, technical support, training in using technology, access to technology, and understanding technology. It is obvious that the barriers faced by PE teachers negatively affect their level of technological innovation use. However, PE teachers should keep students physically active during distance education and gym classes to ensure their socialization and cognitive development. Therefore, they should learn to use the necessary technological tools for this purpose. In summary, providing various training programs on technological innovations for older/longer-serving PE teachers,

especially those working in public schools and middle schools, will increase their interest in technology. This would also reduce the barriers they face. Thus, providing more access to technological innovations in schools with the support of the Ministry of National Education, in-service seminars, and school management support for technological innovations will make it easier for PE teachers to adopt, use, and apply these innovations.

This study was conducted with Turkish PE teachers. Therefore, comparative studies with other teachers in different education branches and different countries should be conducted in the future. Moreover, qualitative studies could be conducted by asking PE teachers for their opinions according to their roles in diffusing technological innovations. Finally, the effects of PE teachers' social networks in applying and diffusing technological innovations could be examined as well.

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Article

Exploring the Factors That Influence K-12 Teachers' Use of Open Educational Resources

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Abstract: The features of open educational resources (OERs) have the potential of enhancing teaching effectiveness and student learning experiences in K-12 education. Encouraging K-12 teachers to use OERs requires an understanding of the factors that have an influence on teachers' decisions to adopt or use OERs in their teaching. In this regard, this study explored the factors related to how teachers perceived their use of OERs, including the perceived ease of use of OERs, perceived usefulness of OERs, intention to adopt OERs, attitudes, OER self-efficacy, and so on. The relationships of several proposed factors were explored. The participants were teachers from a university in the northeastern United States. Both quantitative and qualitative approaches were applied to analyze the collected data. The results indicated that teachers' perceptions of using OERs were positive overall. Their perceived ease of use and usefulness were two significant predictors of teachers' adoption of OERs. Other factors that addressed teachers' willingness and challenges with the use of OER were reported and discussed.

Keywords: open educational resources (OERs); self-efficacy; K-12 teachers' perceptions; factors; challenges

1. Introduction

The use of open educational resources (OERs) has been increasing in K-12 and higher education [1,2]. Open educational resources (OERs) are free and open-licensed educational materials and resources [3]. OERs enable the creation of free and universally accessible educational materials that can be used by anyone for teaching or learning purposes [3]. UNESCO defined OERs as "The open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes" [4] (p. 24). The formats of OERs vary across a wide range, including courses, textbooks, music, videos, simulations, test items, journal articles, and other resources that are usually available online and without access fees [3,5]. The use of OERs provide users with permission to engage in the 5 R activities, which include retaining, remixing, revising, reusing, and redistributing the resources [5,6].

The demand for OERs in K-12 is on the rise [1]. OERs have the potential to shift instruction from a one-size-fits-all model to a well-versed differentiated model in K-12 schools [7]. Traditional textbooks, although the primary sources of learning materials, fail to accommodate teachers' preferences, teaching styles, and students' learning needs [8,9]. Other issues related to the use of textbooks include teachers' lack of control of content presentation, high subscription fees, copyright restrictions, and the lack of the capability for instant content updates [10]. With the features of no cost and easy access, OERs are suggested to be a cost-effective alternative to traditional textbooks which helps to achieve differentiated instruction [11,12]. OERs provide teachers with adaptable and free learning

resources that are accessible to all students, especially to those who cannot afford expensive textbooks [10,12]. The use of OERs may also help alleviate the issues of digital divides and promote social justice [7].

The adoption and use of OERs have become a trend in K-12 education [13]. The use of OERs has the potential to enhance students' academic achievement and learning motivations [11,14]. Through initiatives and professional development training, school teachers are provided with opportunities to not only learn of the potential of OERs in facilitating teaching, but also are encouraged to implement OERs in their class [12,14]. With more K12 teachers introduced to OERs, it is important to understand their perceptions of adopting and using OERs in teaching, especially the factors related to the intention of teachers towards OER adoption [12,13,15]. Few studies have investigated K-12 teachers' perceptions of adopting OERs [12]. To increase our understanding in this regard, this study aims to investigate teachers' perceptions of using or adopting OERs, with a focus on several proposed factors, such as their intention to adopt OERs, perceived usefulness, ease of use, etc.

2. Literature Review

2.1. Teachers' Perceptions of Using OER: Technology Acceptance Model and Other Related Variables

Based on Fishbein and Ajzen's [16] Theory of Reasoned Action (TRA), Davis [17] developed a Technology Acceptance Model (TAM) to describe individuals' adoption of information technology. The TAM has been widely applied to understand how individuals adopt or use a new technology tool in various fields, such as management, information systems, psychology, and education [18,19]. Individuals' desire to use or adopt a new technology is influenced by several variables related to their beliefs or attitudes [20]. In the TAM, perceived ease of use and perceived usefulness are two important factors that explain individuals' intention to adopt or use technology [17]. Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" [17] (p. 320). Perceived usefulness refers to "the degree to which a person believes that using a particular system would enhance his or her job performance" [17] (p. 320).

In K-12 education, the TAM has been considered as an important model that helps describe teachers' perceptions of using or adopting new technology [12,18,21]. Teo et al. [22] conducted a study that involved pre-service teachers and found that perceived usefulness and perceived ease of use had a significant effect on their intention to use technology. Granić and Marangunić [21] conducted a systematic review and found that both perceived ease of use and perceived usefulness determine teachers' intention towards technology adoption, and that perceived usefulness has a stronger effect on teachers' intention to adopt technology, compared to perceived ease of use. In terms of OERs, limited research has been conducted to examine users' perceptions of OER adoption based on the TAM. Kim et al. [20] investigated students of the Open University in Korea and found that perceived ease of use was a significant predictor of their intention to use OERs, but perceived usefulness was not a significant predictor of their intention of OER adoption. Tang et al. [12] investigated 68 teachers' intentions to adopt OERs in K-12 settings in the United States, and found that both their perceived ease of use and perceived usefulness significantly predicted their intention to adopt OERs.

In addition to perceived ease of use and perceived usefulness, Kim et al. [20] proposed other variables that help to address users' perceptions of using OERs. These variables include attitudes, subjective norms, and OER self-efficacy. Attitudes is defined as "a belief in the expected outcomes of such behaviors" and subjective norms as "a belief in how other people think of the behaviors" [20] (p. 5). OER self-efficacy refers to users' confidence level in using OERs for required tasks [20] (p. 5). In this study, we included these three variables to describe teachers' perceptions of adopting OERs in addition to the three variables in the TAM (i.e., perceived ease of use, perceived usefulness, and intention).

2.2. Technology Self-Efficacy and Technology Integration Self-Efficacy

Self-efficacy was defined by Bandura [23] as “People’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives” [23] (p. 71). Self-efficacy is related to several outcomes, such as goal setting, striving for learning tasks, and achievement [23]. People with higher levels of self-efficacy are more likely to set higher goals and be persistent compared to those with lower levels of self-efficacy [24]. The concept of self-efficacy has gained attention in and been applied to various fields, such as management, information systems, education, etc. [25].

Self-efficacy is linked to teachers’ perceptions of their ability to provide meaningful learning experiences to their students, and their willingness to explore and experiment with new instructional strategies or technology tools [26]. Technology self-efficacy and technology integration self-efficacy are important factors that may have an influence on teachers’ intention to adopt new technology tools [18]. In the context of this study involving teachers, technology self-efficacy refers to the degree to which teachers are confident in their ability to use computers to perform various tasks [27]. Technology integration self-efficacy refers to teachers’ belief in their capabilities to successfully integrate technology into their teaching [18,26].

Teachers’ technology self-efficacy is associated with teachers’ technology use behavior in the classroom [28]. Teachers with higher levels of technology self-efficacy are more likely to show positive attitudes towards integrating new or innovative technology tools into their teaching [28,29]. Teachers with higher levels of technology integration self-efficacy are more willing to explore or try out new ideas or experiments with technology when developing teaching materials compared to their counterparts [18]. In our study, we assume that teachers with higher levels of technology self-efficacy and technology integration self-efficacy are more likely to possess higher levels of self-efficacy in using OERs.

3. Research Questions

1. What are teachers’ perceptions of using OERs?
2. Do teachers’ perceived ease of use of OERs and perceived usefulness of OERs predict their intention to adopt OERs?
3. Is OER self-efficacy correlated with technology self-efficacy and technology integration self-efficacy?
4. What are the factors that influence teachers’ willingness to use OERs?
5. What are teachers’ perceived challenges of using OERs in teaching?

4. Methods

4.1. Participants

The participants included 23 teachers enrolled in a graduate-level educational technology course (see Table 1). This course was offered online through the College of Education at a northeastern university in the United States. There were more female teachers (69.6%) than male teachers (30.4%). Most of the teachers were aged between 20 and 30 (47.8%) or 31 and 40 years old (43.6%). About 8.6% were teachers at or above the age of 41 years. About 52.2% of the teachers had taught for 1–5 years, and 26.1% had for 6–10 years. There were a few teachers (21.7%) who had taught for 10 years or more. As for teachers’ self-rated technology skills, more than half of the teachers (56.5%) described themselves as technology experts. About 34.8% of them indicated that they possessed substantial technology skills. Only a few of them (8.7%) had moderate technology skills.

Table 1. Background information.

Characteristics	<i>n</i>	%
Gender		
Male	7	30.4
Female	16	69.6
Age		
20–30	11	47.8
31–40	10	43.6
41–50	1	4.3
51–60	1	4.3
Years of teaching experiences		
1–5	12	52.2
6–10	6	26.1
11 and above	5	21.7
Technology skills (self-rated)		
Moderate	2	8.7
Substantial	8	34.8
Expert	13	56.5

4.2. Data Collection

Data were collected using an online survey. This study was approved by the university’s Institutional Review Board (IRB), and informed consent forms were obtained from the teachers who participated in the survey. The online survey was provided to teachers at the end of the semester. The survey questionnaire consisted of sections such as student background information, their perceptions of using OERs (i.e., perceived ease of use of OERs, perceived usefulness of OERs, intention to adopt OERs, attitude towards OERs, subjective norm regarding OERs, and OER self-efficacy), self-efficacy related to technology use and technology integration (see Table 2), and reflection. Student background information included gender, age, years of teaching experience, and technology skills.

Table 2. Instruments.

Scales	Number of Items	Range	Cronbach’s Alpha
Perceived ease of use of OERs	3	1–7	0.91
Perceived usefulness of OERs	3	1–7	0.91
Intention to adopt OERs	2	1–7	0.90
Attitude towards OERs	3	1–5	0.92
Subjective norm regarding OERs	3	1–5	0.80
OER self-efficacy	2	1–5	0.80
Technology self-efficacy	12	1–7	0.83
Technology integration self-efficacy	6	1–6	0.94

The three scales, including the perceived ease of use of OERs, perceived usefulness of OERs, and intention to adopt OERs, were adapted from the scales developed by Teo [29] that were used to measure teachers’ technology acceptance, and were tested with good reliability (i.e., composite reliability values larger than 0.93) and validity (i.e., convergent validity and discriminant validity). The scales measuring teachers’ perceived ease of use of OERs and usefulness of OERs have three items each. The intention-to-adopt-OERs scale has

two items. All of these three scales were 7-point Likert scales. The three scales including the attitude towards OERs, subjective norm regarding OERs, and OER self-efficacy were adopted from the instrument developed by Kim et al. [20] that measured adult learners' adoption of OERs. These three scales were established with good reliability (Cronbach's alpha values larger than 0.80) and content validity. They were 5-point Likert scales. The items for these three scales included, for example, "I am positive towards OER", "What OER stands for is important for me as a learner", and "I have the necessary skills for using OER".

The technology self-efficacy scale adopted for this study is a 7-point Likert scale that includes twelve items measuring users' confidence in performing computer-related tasks [30]; for example, "I can always manage to solve difficult computer problems if I try hard enough". The technology integration self-efficacy scale that we adopted for this study has six items to measure how confident the teachers are in integrating technology into teaching. This scale was developed by Moore-Hayes [26] and it is a 6-point Likert scale. One item, for example, is "How well prepared are you to evaluate software to support teaching and learning?" Table 2 provides an overview of each scale. Both scales were established with good reliability and validity (through exploratory factor analysis). The reliability values of the scales in this study ranged from 0.80 to 0.94.

4.3. Context

Teachers enrolled in the course were required to work on an assignment about OERs. This assignment provided teachers with opportunities to learn about the concept and potential of OERs in teaching, as well as to explore available OERs, such as OER platforms, websites, or tools that can be useful for teachers in K-12 settings. Teachers were asked to review existing OER lessons and teaching materials that were developed by others, share their viewpoints with classmates about the OERs that they had explored, and how they felt these free OERs or materials would benefit their teaching by participating in online discussion boards.

4.4. Data Analysis

Data were analyzed using a quantitative approach via SPSS 28. The quantitative approaches included descriptive analysis, and correlation and regression analyses. Data were analyzed using quantitative and qualitative approaches. SPSS 26 was used for data analyses. A qualitative approach was adopted to analyze the open-ended questions related to factors that teachers considered when using or adopting OERs, and challenges that teachers encountered when using OERs. Descriptive analyses were performed to answer research question one. A regression analysis was performed to answer research question two about the prediction of two proposed variables on intention. Correlation analyses were conducted to answer research question three about the correlation of OER self-efficacy with technology self-efficacy and technology integration self-efficacy. Content analysis was performed to answer research questions four and five, to further understand the potential factors that influence teachers' use of OERs and the challenges they may encounter.

5. Results

5.1. RQ1: What Are Teachers' Perceptions of Using OERs?

Table 3 shows the teachers' average scores for the six instruments that measure their perceptions of OER use. The average score of teachers' perceived ease of use of OERs was 6.29, which is above the midpoint 4. The average score of teachers' perceived usefulness of OERs was 6.49. Teachers had a slightly high average score of their intention to adopt OERs ($M = 6.52$, $SD = 0.67$). The average score for teachers' attitudes towards OERs was moderately high ($M = 4.19$, $SD = 0.47$). The average score of teachers' subjective norm regarding OERs was 3.9, slightly above the midpoint 3. Teachers had a moderate average score for OER self-efficacy ($M = 4.41$, $SD = 0.51$).

Table 3. Descriptive information.

Scales	Range	Midpoint	M	SD
Perceived ease of use of OERs	1–7	4	6.26	0.69
Perceived usefulness of OERs	1–7	4	6.49	0.61
Intention to adopt OERs	1–7	4	6.52	0.67
Attitude towards OERs	1–5	3	4.19	0.47
Subjective norm regarding OERs	1–5	3	3.90	0.55
OER self-efficacy	1–5	3	4.41	0.51

5.2. RQ2: Do Teachers' Perceived Ease of Use of OERs and Perceived Usefulness of OERs Predict Their Intention to Adopt OER?

The multiple regression model (see Table 4) was significant: $F(2, 20) = 20.55, p < 0.001$. The model explained 67% of the variance in the intention to adopt OERs. The perceived ease of use of OERs ($\beta = 0.294, p < 0.05$) and perceived usefulness of OERs ($\beta = 0.657, p < 0.001$) significantly predicted teachers' intention to adopt OERs. Among the two variables, the perceived usefulness of OERs was the strongest predictor of perceived learning.

Table 4. Multiple regression model: perceived learning explained by three predictor variables.

Variables	B	SE B	β	t	p
Perceived ease of use of OERs	0.284	0.135	0.294	2.10	0.048 *
Perceived usefulness of OERs	0.716	0.152	0.657	4.70	0.000 ***

Note: * $p < 0.05$; *** $p < 0.001$.

5.3. RQ3: Is OER Self-Efficacy Correlated with Technology Self-Efficacy and Technology Integration Self-Efficacy?

Table 5 indicates the correlations between teachers' OER self-efficacy, technology self-efficacy, and technology integration self-efficacy. OER self-efficacy was positively related to technology self-efficacy ($r = 0.42, p < 0.05$) and technology integration self-efficacy ($r = 0.54, p < 0.01$). Technology self-efficacy is positively correlated with technology integration self-efficacy ($r = 0.67, p < 0.01$).

Table 5. Correlations among variables.

	OER Self-Efficacy	Technology Self-Efficacy	Technology Integration Self-Efficacy
OER self-efficacy	—	0.42 *	0.54 **
Technology self-efficacy		—	0.67 **
Technology integration self-efficacy			—

Note: * $p < 0.05$; ** $p < 0.01$.

5.4. RQ4: What Are the Factors That Influence Teachers' Willingness to Use OERs?

Teachers indicated several factors that may influence their willingness to use or adopt OERs in teaching. Many teachers indicated that the ease of use of OERs and that there was no cost were two major factors that had an impact on their decision to use OERs. They felt that it was easy for both teachers and students to use, access, or share OERs with others. Several teachers indicated that the use of OERs would save course preparation time and provide more interactive or enhancing lesson resources that would help increase student engagement, interest, and motivation to learn. In addition, teachers indicated the potential of OERs in tracking student progress and improving differentiated instruction. In addition, other factors that teachers considered when using OERs included standard alignment compatibility, the time spent in searching for OERs, and the capability of the school's technology infrastructure. Below are some of the statements shared by teachers:

"Free, already created, can see what other people do/how they teach a topic, lessens burden on instructors."

"Has a range of applications that improve student's education and learning. Many of these applications have features that track individual student learner which can help the teacher track student's progress."

"The main factor would be increasing student engagement and finding activities that interest my students to enhance their learning."

"The ease of accessibility for my students, the range of various activities that my students can use, and the relevance of the platform to what I'm teaching."

5.5. RQ5: What Are Teachers' Perceived Challenges of Using OERs in Teaching?

In terms of the challenges that teachers encountered when using OERs in teaching, the challenges that were most often brought up by teachers included the lack of knowledge or awareness of OERs, lack of training opportunities related to OERs, the reliability/quality of OERs, and the lack of alignment of OERs with content or curriculum standards. Some teachers described that there was a learning curve for them to learn about OERs and then use them in the classroom. It was time-consuming sometimes for them to search and identify high-quality OER content or resources that were aligned with their teaching needs, student needs, or content standards. Other issues that teachers indicated included the lack of technical support for teachers and students, no approvals of the use of OERs by the school district, schools not having an adequate technology infrastructure to handle or maintain the usage of OERs, and students not possessing the ability to use OERs appropriately (e.g., copying the content from the answer keys). Below are some of the challenges shared by teachers:

"Having to fact-check anything for Social Studies or teaching it can be tedious at times. Also, I would need to make sure the content aligns with learning standards and objectives."

"The challenges of using OER is having to make sure they aligned with what you are teaching and not everything found is always factual or correct."

"The ability of my school's technology infrastructure to reliably handle the usage of an OER is a challenge. My student's ability to use the OER at home is also a challenge."

"One of the biggest challenges that I face is knowing an open educational re-source exists but not being entirely comfortable with how it works."

"One challenge I have encountered is students opening accounts for the same resources educators have access to. They then take the answer keys for the worksheets or activities we have used in the classroom. I have seen the same exact answers in my student's work as shown in the answer key, word for word."

6. Discussion

Overall, teachers' perceptions of using OERs in teaching were quite positive. Most teachers found OERs easy to use, perceived OERs as useful resources, and their intention was to use or adopt OERs in their teaching. Teachers' attitudes towards and belief about the use of OERs were positive. Teachers' OER self-efficacy was moderately high, indicating that most teachers were confident in their ability to find or use OERs.

According to our regression analysis, teachers' perceived ease of use of OERs and perceived usefulness of OERs were two significant predictors of their intention of OER adoption. Teachers' perceived usefulness was the stronger predictor of teachers' intention of OER adoption, compared to their perceived ease of use of OERs. This finding is consistent with previous research TAMs that indicated that teachers' intention to adopt new technology was influenced by the perceived ease of use and usefulness of that specific technology tool [12,21]. Tang et al. [12] also found that teachers' perceived usefulness was

a stronger predictor of their intention to adopt OERs than their perceived use of ease in their study that involved 68 teachers enrolled in an online course.

In terms of self-efficacy, teachers' OER self-efficacy was found to be significantly correlated with technology self-efficacy and technology integration self-efficacy. Teachers with higher confidence levels in using computers or incorporating technology into teaching were more likely to have higher levels of self-efficacy in using OERs. It makes sense that teachers who possess higher confidence levels in handling computer-related tasks or resolving relevant issues related to computer use are more likely to use OERs in teaching, as OERs are accessible through different websites or platforms, and the use of OERs often requires the use of the Internet and computers [3]. Teachers who have higher levels of confidence in incorporating various types of technology tools into teaching are more open to trying out new technology, such as OERs, and using it to enhance their teaching.

Based on the data analysis, factors such as ease of use, no cost, easy access, sharable features, saving course preparation time, etc., were found to be influential on teachers' decision to use or adopt OERs in their teaching. This result corresponds to the findings of an OER study conducted by Tang et al. [12]; teachers perceived OERs as easy to use and easily accessible. Similar to the quantitative part of this study, the ease of use of OERs was also identified as an important factor by teachers in our qualitative analysis. Our study also found that the use of OERs has the potential to improve differentiated instruction, which helps teachers to teach beyond the use of textbooks [10,14]. In addition, schools' technology infrastructure was another important factor that had an impact on teachers' decision to use OERs. Previous research indicated that an unsupportive environment or inadequate support would influence teachers' intention to use OERs [13].

The major challenges identified by teachers in this study included teachers not possessing enough knowledge of OERs, limited OER training opportunities, and issues related to the quality of OERs, the alignment of OERs to content or curriculum standards, technical support, students' ability to use OERs, etc. Similar to Tang's [13] study that investigated teachers' barriers to the use of OERs, quality assurance, technical support, and proficiency in finding OERs were some of the barriers that impeded teachers from using OERs. In our study, the two challenges we recorded, including concerns about OERs in terms of their alignment to content standards, and students not having the ability to use OERs appropriately, were not identified in prior research. Although OERs are free and easy to access, teachers prefer to have OERs that include information about how these resources are aligned with the standards of the content or curriculum they teach. In addition, students may not possess adequate knowledge or skills when using OERs, which may lead to plagiarism issues in students' submissions of assignments or homework.

7. Conclusions and Implications

Overall, in this study, K-12 teachers' perceptions towards the use or adoption of OERs in their teaching were quite positive in all six facets, including the perceived ease of use of OERs, perceived usefulness of OERs, intention to adopt OERs, attitude towards OERs, subjective norm regarding OERs, and OER self-efficacy. Teachers' perceived ease of use and perceived usefulness significantly predicted teachers' intention to adopt OERs. Compared to the perceived ease of use, perceived usefulness was found to be a stronger predictor of teachers' intention to use OERs. Teachers' technology self-efficacy and technology integration self-efficacy were positively related to their OER self-efficacy in a significant way. Qualitative analysis summarized the factors that had an influence on teachers' willingness to use or adopt OERs, as well as the factors concerning teachers' challenges with implementing OERs in their teaching.

The findings of this study provided practical implications for educators, administrators, course designers, and practitioners. First, training or professional development opportunities on OERs should be provided to teachers so that they are aware of OERs as learning resources that they can use freely and that are easy to use. Second, reaching out to teachers with low technology or technology integration self-efficacy, and providing

them with additional support will help increase their confidence in using OERs. Third, course designers should develop OERs that are in alignment with content or curriculum standards and pay attention to the quality of their OERs to motivate teachers to adopt them in their teaching. Last, sharing successful examples or cases may enhance teachers' interest in adopting OERs. There are several limitations of this study. The sample size of this study is small, and we suggest that future researchers include a larger sample in their research to further verify the findings of this study. In addition, we may not have captured all of the factors that had an influence on teachers' intention to adopt OERs in this study. There may be some other factors (e.g., self-efficacy, prior experiences, etc.) that are of importance to teachers from other cultures or countries and worth further investigation.

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Generative AI-Based Platform for Deliberate Teaching Practice: A Review and a Suggested Framework

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Abstract: This paper begins with a comprehensive review of the deliberate teaching practice literature related to generative AI training platforms. It then introduces a conceptual framework for a generative AI-powered system designed to simulate dynamic classroom environments, allowing teachers to engage in repeated, goal-oriented practice sessions. Leveraging recent advances in large language models (LLMs) and multiagent systems, the platform features virtual student agents configured to demonstrate varied learning styles, prior knowledge, and behavioral traits. In parallel, mentor agents—built upon the same generative AI technology—continuously provide feedback, enabling teachers to adapt their strategies in real time. By offering an accessible, controlled space for skill development, this framework addresses the challenge of scaling and personalizing teacher training. Grounded in pedagogical theory and supported by emerging AI capabilities, the proposed platform enables educators to refine teaching methods and adapt to diverse classroom contexts through iterative practice. A detailed outline of the system’s main components, including agent configuration, interaction workflows, and a deliberate practice feedback loop, sets the stage for more personalized, high-quality teacher training experiences, and contributes to the evolving field of AI-mediated learning environments.

Keywords: teacher training; deliberate practice; generative training; virtual students; large language models; LLM; simulation; personalized instruction

1. Introduction

Training effective teachers is a complex and time-consuming task. The famous “10,000 h rule” could be used to reference teacher training duration. The “10,000 h rule” states that the key to achieving expertise in any domain is a sufficient amount of practicing with at least 10,000 h as a common rule of thumb for time spent on the activity to reach the mastery level in it (Gladwell, 2008; Nichols et al., 2018; Cranford, 2022). However, not all practices are equally helpful in developing a desired set of skills (various teaching and pedagogical skills in this context). Deliberate practice (Ericsson et al., 1993; R. H. Chen, 2022) is a high-quality practice that includes goal-directed activities while focusing on improving one’s weaknesses with appropriate feedback from a high-quality mentor.

Unfortunately, acquiring sufficient experience for a teaching professional is very slow. Using some estimates, 5000 h of teaching practice amounts to 5–6 years of teaching experience (Cuban, 2010; Stich & Cipollone, 2021). Moreover, these experiences are rarely deliberate as most of them are not supported by feedback from qualified mentors and do not include repetitive exercises for teaching specific material to students or a class

with certain backgrounds or learning profiles. In addition, unlike many other professions, gaining experience through trial and error might have a significant cost for students in the class of a less experienced teacher. Therefore, there is a need for a drastic increase in the quantity and quality of teaching practice during teachers' training and the initial induction period (Ingersoll & Strong, 2011). There is also a need to provide teachers with new digital applications that will be added to the traditional tools they apply in their teaching (Abedi, 2023).

This paper describes a new conceptual framework for a practical teaching simulation platform using recent advances in simulating group dynamics (Y. Li et al., 2023) and expert feedback (Sonnemann & Blane, 2024). These advances were enabled by the advent of large language models (LLMs), generative AI (Soliman et al., 2024), and collaborative agents. In this platform, students will be represented by a collection of large language model (LLM)-driven agents primed with specific behavioral traits (Jiang et al., 2023), learning patterns, and prior knowledge. The platform will also contain mentor LLM agents to monitor class interaction and provide feedback on teacher performance and helpful improvement suggestions.

Using this platform, aspiring and young teachers could practice deliberately while polishing their skills through the repetitive teaching of specific subjects to students and classes of controlled compositions, behavioral traits, and backgrounds. The mentor LLM agents will monitor the class dynamics, difficulties, and questions asked by virtual students and suggest possible improvements in teaching approaches (Marcus et al., 2020).

During the previous decade, virtual reality was considered the cutting edge of technology, and its use had spread considerably in training and teaching (Malik et al., 2024). However, its development costs were far beyond the reach of a large part of the education system (Extremera et al., 2020). Thus, a more affordable solution was required (Urueta, 2023). The recent advent of LLMs, their capabilities, availability, and price make them an attractive solution for classroom simulations (Lyu et al., 2024). In particular, the ability of LLMs to play roles and personalities enables them to supply, in the form of agents, an environment of chosen personas, including students and mentors (Alsafari et al., 2024). These abilities were recently used to simulate a class environment (Y. Zhang et al., 2024; B. Hu et al., 2024) and to leverage LLM-driven multiagent systems to construct an AI-augmented classroom (Yu et al., 2024). Finally, B. Hu et al. (2024) recommended the future development of a teacher training platform.

Thus, according to the recommendation of B. Hu et al. (2024), we propose a teacher training platform that uses an LLM-based multiagent environment that simulates various students in a class environment and mentors outside the class. The teacher's encounter with these personas is integral to gaining teaching experience and improving teaching capabilities.

This paper continues as follows: Section 2 reviews the literature; Section 3 describes the proposed framework; Section 4 describes a use case; Section 5 analyses the use case and the framework and draws some conclusions and practical takeaways; and Section 6 concludes the paper.

2. Literature Review

To set the stage for our framework, we examine the emergence of LLMs and multi-LLM agents, discuss simulation-based practice, explore tools for modeling and constructing the simulation platform, and address how simulation teaching models can be evaluated.

2.1. The Advent of LLMs and Their Capabilities

There has been impressive progress in generative AI recently, specifically in models for natural language understanding and dialogue. Modern large language models (e.g., ChatGPT 4) surpass the grades of an average student in many standardized tests (OpenAI, 2023), including SAT math, reading and writing, and even the Uniform Bar Exam.

Table 1 presents GPT-4's final score graded on standardized exams, as well as the percentile of test-takers achieving GPT-4's score compares GPT-4's performance to human students on standardized exams, highlighting how generative AI now matches or surpasses human abilities in several fields.

Table 1. GPT performance on standardized exams (based on data from OpenAI, 2023).

Exam	GPT-4	GPT-4 (No Vision)	GPT-3.5
Uniform Bar Exam (MBE+MEE+MPT)	298/400 (~90th)	298/400 (~90th)	213/400 (~10th)
LSAT	163 (~88th)	161 (~83rd)	149 (~40th)
SAT			
Evidence-Based Reading & Writing	710/800 (~93rd)	710/800 (~93rd)	670/800 (~87th)
SAT Math	700/800 (~89th)	690/800 (~89th)	590/800 (~70th)
Graduate Record Examination (GRE) Verbal	169/170 (~99th)	165/170 (~96th)	154/170 (~63rd)

Moreover, the rate of improvement in reasoning and text generation abilities is impressive, with additional modalities such as voice, images, and videos being integrated and refined. Although state-of-the-art models excel in English, models focusing on other languages are quickly catching up. Significant effort was invested in designing an efficient way to customize generic LLM models for specific domains via fine-tuning (Han et al., 2024), adapters (Z. Hu et al., 2023), or Retrieval-Augmented Generation (RAG) methods (J. Li et al., 2024).

In addition to standardized exams, LLMs have made significant strides in tasks like the Turing Test, which evaluates a machine's ability to exhibit intelligent behavior indistinguishable from a human (Sejnowski, 2023). While no model has fully "passed" the Turing Test in its original formulation, modern LLMs have come remarkably close in many conversational contexts. For instance, GPT-4 and similar models can engage in nuanced, context-aware dialogues that often deceive human judges into believing they are interacting with another person (Bubeck et al., 2023). This capability is particularly evident in customer service, therapy chatbots, and educational tutoring, where LLMs can provide responses that are not only coherent but also empathetic and contextually appropriate (Z. Zhang et al., 2024). These advancements suggest that LLMs are approaching a level of conversational sophistication that challenges traditional notions of human uniqueness in language and reasoning.

In the context of this research, fine-tuning models on a text corpus describing pedagogical concepts might help to improve mentor agents for providing more accurate feedback on teaching approach and class dynamics. Another line of research explores how to make models unlearn selected facts and concepts (Eldan & Russinovich, 2023; Si et al., 2023). While this work provides a different motivation (i.e., copyright concern), the same techniques can be used to produce student LLM models that lack specific knowledge. This will allow an objective evaluation of the teaching strategy based on test performance before

and after the teaching session. Additionally, LLM models that lack specific knowledge can provide valuable insights into areas where teaching strategies may need improvement.

2.2. Multiple Collaborative LLM Agents

Multiple LLM agents collaborate in natural language in multiagent frameworks to achieve a common goal. Usually, each agent is primed with a specific role, background story, available documents, and skills. Naturally, this development has fueled the line of research dealing with simulating human behavior and dynamics by a committee of LLM-based agents. Inspired by the rapid progress of LLMs, an even more powerful multiagent approach has emerged (Park et al., 2023). In the groundbreaking work by Park et al. (2023), a community of 25 agents was released in a virtual town inspired by The Sims game. Each agent's identity, including occupation and relationships, was described in a one-paragraph natural language seed memory. In a short period of time, the agents demonstrated believable social interactions and behavior. Since this research, simulating human behavior with LLMs has become a mainstream research direction, producing a steady and increasing flow of research papers, experiments, and software libraries for developing LLM-based multiagent applications for educational purposes (Ren et al., 2024; La Cava et al., 2024; Zhou et al., 2023; Zhao et al., 2023; Törnberg et al., 2023).

2.3. Simulation-Based Practice

Simulation-based practice is a well-established educational strategy for developing professional competency in a wide array of fields—such as teaching, healthcare, aviation, and military training—by offering realistic, controlled environments that foster experiential learning and facilitate iterative skill refinement (Badiee & Kaufman, 2015; Mikeska et al., 2021; Ledger et al., 2025; Hou et al., 2024). Early attempts at developing education-based simulation leveraged virtual reality technologies with manually defined behavioral scripts for digital simulation (Delamarre et al., 2021; Landon-Hays et al., 2020; Ledger et al., 2025). These systems still use well-trained human actors playing various roles. The advent of avatars and LLM agents generated a new generation of replacements for these well-trained human actors. Numerous efforts exist to create software-based simulation platforms for professional learning (Agyei, 2024; Zheng et al., 2024; Gaviria et al., 2024). Agyei (2024) reports the experience and perspectives of prospective teachers. Zheng et al. (2024) describe a simulation teaching platform for intelligent manufacturing, Gaviria et al. (2024) report the use of simulation for enhancing accounting teaching in higher education, and Sonnemann and Blane (2024) compare three established leading simulation systems. Table 2 compares three digital simulation platforms for teacher training: SimTeach, Proxima, and Teacher Moments.

Table 2. Comparison of three digital simulation platforms for teacher training *.

	SimTeach	Proxima	Teacher Moments
Type	Semi-immersive	Low-immersive	Low-immersive
Established and used	USA, established 2012 Currently used in Australia	UK, established 2022 Currently used in the UK	USA, established 2018 Currently used in the USA mostly
How it works	Virtual student avatars controlled by human actors (human-in-the-loop); interactive conversations; can simulate students, parents, and colleagues.	Text-based scenarios with multiple choice, free text, and voice recording response options; the trainee teacher is given a scenario and then responds.	Text, image, and video-based scenarios with multiple choice, free text, and voice recording response options; the trainee teacher is given a scenario and then responds.

* Data summarized from Sonnemann and Blane (2024).

SimTeach is semi-immersive, using virtual student avatars controlled by human actors for interactive conversations. At the same time, Proxima and Teacher Moments are low-immersive, relying on text, voice, and video-based scenarios with multiple response options. Each platform offers different levels of immersion and interactivity to help trainee teachers practice their skills in simulated classroom environments. However, these approaches are limited to a relatively small number of predefined interaction scenarios and do not allow for personalization to create an intensive, deliberate practice experience as described above. Table 2 summarizes their comparison. In fact, all simulations prior to the recent emergence of commercially available LLMs in 2022, suffer from these drawbacks. However, they were still found to be valuable for the enrichment of teachers' professional training as well as benefitting their professional development (Levin & Muchnik-Rozanov, 2022).

However, the advent of LLMs and their usage in the past two years has enabled a drastically improved simulation. The rapid advancement of generative artificial intelligence enables the creation of more flexible and natural simulation environments for personalized teacher education based on deliberate practice and immediate feedback from AI-based mentors.

Very few papers deal with simulation that uses LLM-based agents and even less so for teacher training (Bhowmik et al., 2024). Bhowmik et al. (2024) present an LLM-powered virtual student conversation agent that they developed for pre-service teacher training in a virtual environment. They found that the simulation with these agents enabled personalized, adaptive training and promoted a more engaging and immersive learning experience for pre-service teachers.

Lee et al. (2023) report about their LLM-based agents: "this research indicates that integrating generative agents into teacher training simulation can be an effective way to offer pre-service teachers with more practical experiences to apply theories and concepts to simulated teaching practices".

2.4. Methodologies for Modeling and Building the Simulation Platform

In software development, "Design Thinking" is a standard methodology for generating personas that simulate different user types. While this approach helps create generalized user models, developing student personas in educational simulations requires more scientifically grounded frameworks. In this context, well-established pedagogical concepts and tools provide the basis for constructing realistic and nuanced student profiles. These studies provide the foundation for building profiles, allowing the simulation platform to accurately capture the complexity of real-world learning environments.

Taxonomies of Learning-Related Cognitive Processes provide a foundational understanding of how student cognition can be modeled. Bloom's Revised Taxonomy (Forehand, 2010; Chandio et al., 2021) categorizes learning into six major cognitive processes: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. These processes operate across four knowledge dimensions: Factual Knowledge, Conceptual Knowledge, Procedural Knowledge, and Metacognitive Knowledge. The application of these categories depends on the knowledge dimension (Widiana et al., 2023), offering a structured approach to the cognitive modeling of students. Another important framework, Marzano's Taxonomy (Marzano & Kendall, 2006; Sun et al., 2023) enhances the cognitive understanding of student learning through six categories: Retrieval, Comprehension, Analysis, Knowledge Utilization, Metacognitive, and Self-System. These are distributed across three knowledge domains: Information, Mental Procedures, and Psychomotor Procedures. Marzano's framework provides more granularity in identifying and modeling student learning behaviors, further enriching the model.

The Pedagogical Relational Teachership Taxonomy (Ljungblad, 2023; Suryani & Syahbani, 2023) emphasizes the relational dynamics between teachers and students, focusing on both Tact and Stance. Each area is divided into six relational key indicators, crucial for describing and simulating the ongoing relational processes in educational settings. These indicators play a pivotal role in modeling how students engage with teachers, making them essential for creating authentic teacher–student interactions in simulations.

A key factor in modeling student profiles is their learning style. Learning styles are defined as “consistent preferences for adopting learning processes, irrespective of the task or problem presented”. Learning styles could be classified along different dimensions. For example, if the dimension is learning modality, the learning styles are visual, auditory, and kinesthetic learning. If the dimension is social attitude, the learning styles are avoidant, participative, competitive, collaborative, dependent, and independent.

The Felder–Silverman Learning Styles Model (Graf et al., 2007; Ikawati et al., 2021) characterizes learners along four major dimensions, each representing a spectrum of preferences for processing and organizing information. *The first* dimension distinguishes between sensing learners, who favor concrete facts and systematic procedures, and intuitive learners, who gravitate toward abstract concepts and theoretical ideas. *The second* dimension contrasts visual learners, who rely on images, charts, and diagrams, with verbal learners, who learn effectively through spoken or written language. *The third* dimension differentiates active learners, who gain understanding by engaging in hands-on activities and discussions, from reflective learners, who require time to think through material and process information privately. Finally, *the fourth dimension* compares sequential learners, who learn in a logical, linear fashion, with global learners, who absorb information in broad strokes and often synthesize knowledge in sudden bursts of insight. Although each dimension presents dichotomous categories, individuals typically blend traits from both ends of each continuum, and recognizing these learning style differences can help educators tailor teaching methods to suit diverse learners.

Maya et al. (2021) and Clavido (2024) explored the relationship between learning styles and academic achievement, which forms a foundation for developing responsive student profiles. Hananto et al. (2024) extended this work by using Support Vector Machines (SVMs) to identify specific learning patterns in students based on Felder–Silverman learning styles. In addition to this model, the Grasha–Riechmann Learning and Teaching Styles framework (Sim & Mohd Matore, 2022) has been validated across multiple cultural contexts, including Argentina (Freiberg Hoffmann & Fernández Liporace, 2021), China (Sim & Mohd Matore, 2022), Iran (Baneshi et al., 2013), and Turkey (Baykul et al., 2010). This framework allows for modeling diverse student personas, reflecting the heterogeneity of real-world classrooms.

2.5. Personality Traits and Learning

Several studies show a strong relationship between personality and learning style (Bruso et al., 2020; Lei, 2022; Singar & Jain, 2024). Two leading personality models characterize personality through several dichotomous characteristics. The older model is the Myers–Briggs Type Indicator (MBTI), and the newer model is the Big Five personality traits. Either one could serve as a proxy for choosing a learning style.

The Myers–Briggs Type Indicator comprises the following four dimensions: Extraversion vs. Introversion, Intuition vs. Sensing, Thinking vs. Feeling, and Judgment vs. Perception. Kang and Kusuma (2020) showed that learning style is related to the MBTI score in the four dimensions. Murphy et al. (2020) found a strong relationship between MBTI personality type and preferred teaching methods for undergraduate college students. Ullah et al. (2024) explored the effect of MBTI personality type on the language learning strategies of non-English major students.

The Big Five personality traits are a group of five characteristics used to study personality:

- Openness to experience (inventive/curious vs. consistent/cautious);
- Conscientiousness (efficient/organized vs. extravagant/careless);
- Extraversion (outgoing/energetic vs. solitary/reserved);
- Agreeableness (friendly/compassionate vs. critical/judgmental);
- Neuroticism (sensitive/nervous vs. resilient/confident).

John et al. (2020) and Mammadov (2022) found a strong relationship between the Big Five personality traits and academic performance. Khalilzadeh and Khodi (2021) found a relationship between teachers' personality traits and students' motivation using structural equation modeling analysis.

2.6. Simulating Social and Emotional Complexities

Large language models (LLMs) have made notable strides in capturing emotional and social subtleties, allowing them to participate in empathetic and contextually fitting exchanges. For instance, GPT-4 can formulate replies that exhibit emotional intelligence—such as offering reassurance in stressful conversations or adjusting its tone to match a user's affect—primarily due to training on extensive datasets encompassing human dialogues, literary works, and psychological materials (Bubeck et al., 2023). These data sources enable LLMs to emulate complex emotional cues and social dynamics.

Despite their capacity to simulate human-like emotional interactions, LLMs do not possess true emotional understanding or consciousness, and their contextually appropriate responses may lack genuine empathy. One way to address this limitation is through a “human-in-the-loop” strategy, wherein human experts direct the model by specifying particular emotional or behavioral intentions. For example, a therapist integrating an LLM into mental health support could craft prompts designed to elicit compassionate and patient responses, aligning with therapeutic objectives (Fitzpatrick et al., 2017). This combined method draws on the language-processing capabilities of LLMs while ensuring that emotional and social sensitivities are shaped by human expertise. Until LLMs can autonomously replicate authentic emotional behavior, such a collaborative framework offers a viable path toward more human-like engagement in settings that require empathy and nuanced understanding.

2.7. Teacher Sense of Efficacy

The Teacher Sense of Efficacy Scale (TSES) (Duffin et al., 2012) has consistently been shown to represent three areas of teaching: efficacy for classroom management (CM), efficacy to promote student engagement (SE), and efficacy in using instructional strategies (IS). Monteiro and Forlin (2023) have shown that the long TSES with 24 items is as valid as the shorter TSES version with 12 items. An important measure of teachers' sense of efficacy is the Teaching and Learning International Survey (TALIS) (Suhandoko et al., 2024). TALIS is an annual international survey on teaching and learning worldwide. It covers teaching-related issues, including training effectiveness and teachers' sense of efficacy (An et al., 2021). For this paper, the important findings are related to the relationship between teacher training and an increased teacher's sense of efficacy. Göker (2020) found a strong relationship between cognitive teacher training and an increased teacher's sense of efficacy. Samuelsson et al. (2021) showed that simulation training gives teachers the same sense of efficacy as teaching pupils. These findings were repeatedly validated in various countries (Monteiro & Forlin, 2023).

2.8. LLM-Based Simulation Platforms for Teacher Training

There are several advanced platforms for developing multiagent applications based on large language models (LLMs), including Autogen (Wu et al., 2023) and Crew AI (CrewAI platform) described by (Berti et al., 2024). Wang et al. (2023) successfully used communication between LLM agents for agent learning. Utilizing these existing tools will allow us to focus on characterizing the system's core features.

Ruiz Rojas et al. (2022) proposed 4PADAFE, a seven-phase methodology for developing an online course while integrating AI. In Ruiz-Rojas et al. (2023), this methodology was expressed in a matrix form. Noroozi et al. (2024) highlighted pedagogical, theoretical, and methodological perspectives on using generative AI in education. Y. C. Chen and Hou (2024) described a framework for employee ethics training using ChatGPT for contextual scaffolding in an interactive educational game designed for teaching ethics. Yue et al. (2024) presented MATHVC, the very first LLM-powered virtual classroom containing multiple LLM-simulated student characters, with whom a human student can practice their math skills.

3. The Framework

3.1. Conceptual Overview of the Platform

This section describes the proposed AI-based platform for deliberate teaching practice. The diagram in Figure 1 presents a high-level description of the proposed platform.

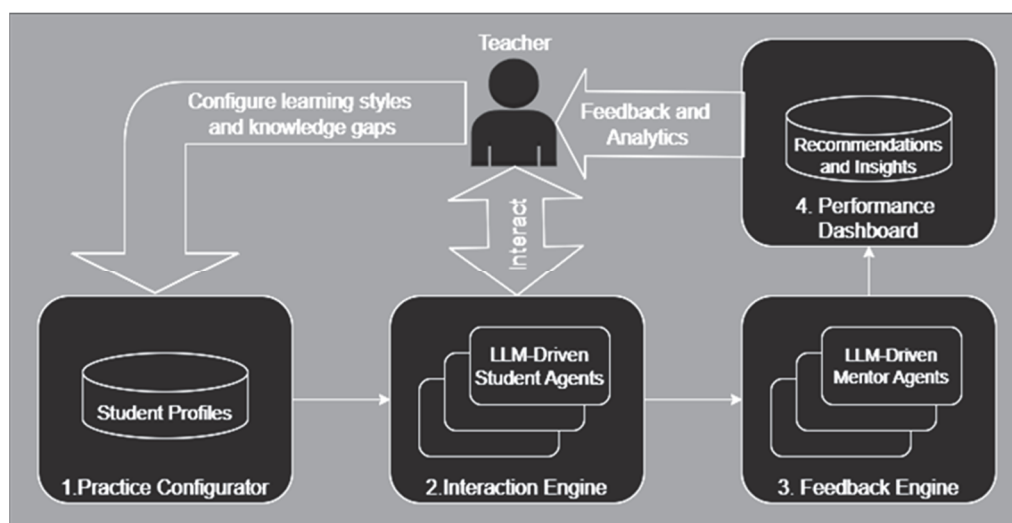


Figure 1. Proposed platform—high-level architecture.

In the proposed model (Figure 1), a teacher starts by defining the objectives and the configuration of the practice exercise (teaching subject, student behavioral patterns, types of questions asked, or expected learning profiles) via the Practice Configurator module (1). The Practice Configurator generates a definition for student agents hosted by the Interaction Engine (2). The teacher interacts with the class (via chat interface addressing an entire class or specific students). All student agents (2) are exposed to class interactions and generate responses or questions based on their individual configuration. The entire class interaction history is saved for future analysis by the mentor agents hosted by the Feedback Engine (3). Using the retained class interaction history, the mentor agents produce the teaching session evaluation and recommendation report that is submitted to the teacher via the Performance Dashboard (4).

3.2. Adaptive LLM-Driven Student Agents

The platform's LLM-driven student agents are designed to emulate diverse, real-world classroom dynamics by simulating various learning styles and behavioral characteristics based on established research. Drawing from the general personality traits and learning styles discussed in the literature review, the agents are modeled to reflect a wide range of learning preferences and personality types. This enables the simulation to offer more realistic and effective student–teacher interactions, allowing teachers to experience and respond to diverse classroom scenarios.

These agents are not static; they adapt over time, simulating student development by exhibiting growth, regression, or behavioral changes based on the teacher's instructional methods. By incorporating these dynamic elements, the platform allows teachers to refine their teaching strategies in an evolving environment, ensuring that they are better equipped to handle the complexities of real-world classrooms. The adaptive behavior of the agents is aligned with theories of learning and personality development, making the simulation a valuable tool for practicing differentiated instruction and personalized teaching.

3.3. Multi-Dimensional Mentor Agents for Feedback

The platform's mentor agents extend beyond traditional feedback systems by offering multi-dimensional insights encompassing various teaching competencies. Rather than focusing solely on lesson clarity or student engagement, these agents provide real-time feedback on critical areas such as classroom management, inclusivity, and emotional intelligence, drawing from theories like the Pedagogical Relational Teachership Taxonomy discussed in the literature review. This ensures that teachers receive comprehensive guidance on managing relational dynamics and fostering a positive classroom environment.

Each mentor agent is programmed to monitor specific aspects of teaching and classroom interactions, delivering tailored feedback that helps the teacher address areas that need improvement. Over time, the mentor agents “learn” from previous sessions, adapting their feedback to target persistent challenges, thus creating a personalized, evolving feedback loop. This iterative process supports the teacher's ongoing development, enhancing their ability to refine instructional techniques and gain deeper insights into effective classroom management and student engagement, aligned with the teacher's sense of efficacy principles.

3.4. Dynamic Classroom Simulation

The platform's classroom simulations are designed to replicate the unpredictable nature of real teaching environments, providing a far more dynamic and authentic experience than static, predefined scenarios. By leveraging insights from LLM-based simulation platforms, such as those discussed in the literature review, the platform introduces real-time adaptive simulations where student behaviors evolve based on teacher interactions. These adaptive elements simulate real-world classroom challenges like spontaneous disruptions, off-topic questions, and varying levels of student engagement.

In the proposed LLM-based class simulations, real teachers interact with a group of AI agents that form the class. These agents are AI-simulated students, having different personas and learning characteristics. It is crucial to note that all classroom communications are visible to both teachers and student agents. In our proposed scheme, the LLM agents generate student responses not only based on the teacher's prompts but also by considering interactions with other simulated student agents. This creates a dynamic and context-aware learning environment where the broader classroom discussion shapes each response. Therefore, teachers should approach these simulations with an awareness of the entire class dynamics, as previous exchanges and evolving discussions influence student responses.

This holistic perspective allows teachers to practice and refine their instructional strategies in a more immersive and interactive setting.

Teachers must adjust their instructional strategies on the fly, cultivating agility and adaptability in their teaching methods. The evolving nature of classroom simulation ensures that educators are better prepared for the complexities of managing diverse student behaviors. It provides valuable practice in navigating actual classrooms' fast-paced and often unpredictable dynamics. This real-time adaptability enhances the realism of the simulation, helping teachers develop the necessary skills to respond effectively to an evolving student body.

Large language models (LLMs) can be strategically harnessed to simulate student behavior tailored to particular local contexts or target audiences (Gao et al., 2024) through two main methods: prompt conditioning and fine-tuning.

First, *prompt conditioning* involves supplying the LLM with locally relevant information from human supervisors, ensuring that the model reflects the unique cultural, linguistic, and educational attributes of a given region or institution (Kienzler et al., 2023). For example, a supervisor might provide local idioms, historical context, or curriculum guidelines, enabling the LLM to produce responses that resonate more strongly with the target audience.

Second, *fine-tuning* on real classroom transcripts from target schools or institutions equips the LLM with a deeper understanding of the specific communication styles, academic challenges, and interaction patterns found in those environments (Ilagan et al., 2024). This process ensures that the simulated students exhibit realistic academic behaviors and align with the institution's pedagogical aims (Radford et al., 2021).

By combining these strategies, educators can create highly context-aware simulated students for teacher training, curriculum development, and educational research. This approach merges human expertise with the scalability of LLMs, allowing for customized learning experiences that meet the distinct needs of learners while preserving essential cultural and contextual nuances.

3.5. Multi-Method Adaptive Deliberate Practice

At the heart of the platform is a multi-method deliberate practice framework, where teachers engage in repeated teaching cycles of the same subject matter but with varying configurations of student agents. This approach draws from established simulation-based practice methods discussed in the literature review, allowing teachers to experiment with different instructional strategies, such as inquiry-based and project-based learning.

Each practice cycle allows teachers to focus on refining specific teaching techniques by experiencing diverse student reactions and classroom dynamics. The structured repetition ensures that teachers can analyze how different approaches affect student outcomes, helping them develop a versatile toolkit to address various classroom challenges. Throughout these cycles, mentor agents provide continuous, targeted feedback, guiding teachers in refining their methods and reinforcing key teaching strategies over time. This iterative process aligns with the principles of deliberate practice, ensuring that teachers can iteratively refine their skills in a controlled yet dynamic environment.

3.6. Evaluation Methods

Our platform employs a multi-faceted evaluation model, integrating three data-driven methods for assessing system performance: (a) subjective (Ngereja et al., 2020), (b) objective (Wen & Ji, 2020), and (c) simulation-based (Robinson et al., 2024). The subjective evaluation collects participant feedback (teachers, mentors, and students) through surveys to assess the perceived effectiveness of the training, following frameworks such as those outlined

by Fernandes et al. (2023). This method provides valuable insights into the participants' experiences but is inherently subjective.

For a more concrete analysis, we use objective evaluation, which measures student progress in a specific subject depending on the method of instruction (Grădinaru et al., 2021; Mohan, 2023). This approach evaluates the real impact of teaching strategies on student learning outcomes. Finally, simulation-based evaluation tracks improvements in student agents' scores on standardized tests, providing a reliable way to assess how effectively teachers apply instructional techniques in the simulated environment.

The SLOTE metric (Levin et al., 2023) adds a layer of comprehensive evaluation, combining quantitative and qualitative measures of simulation-based learning (SBL) effectiveness. This metric, which we adopt as a core tool in our evaluation system, is designed to measure the efficiency of teacher training simulations and the learning outcomes that they produce in field experiments.

Early examples of using AI-driven virtual students, such as the one-on-one interaction models based on ChatGPT (Markel et al., 2023), have demonstrated the potential for AI to provide meaningful feedback in simulated learning environments. Similarly, studies such as that by Smith and Holmes (2020) on deliberate practice in physics lab teaching have shown the benefits of combining AI agents with human learners.

3.7. System Architecture

The generative AI-based teacher training platform's system architecture is modular, scalable, and designed to provide personalized, adaptive simulations. Key components work together to create immersive teaching environments, offering real-time feedback and data-driven insights to enhance teacher development. The architecture is focused on ensuring that the platform is adaptable for diverse educational settings, supporting the varied needs of both novice and experienced teachers.

3.7.1. Practice Configurator

The Practice Configurator allows teachers to define parameters for each training session, including subject matter, student behavioral profiles, and class complexity. This feature personalizes simulations, enabling teachers to practice in various environments. Advanced options like adjusting students' socio-emotional characteristics enhance the configurator's flexibility.

3.7.2. Interaction Engine

The Interaction Engine manages real-time teacher–student communication through chat or voice commands, with student agents responding dynamically based on LLM-driven profiles. The engine supports both class-wide and one-on-one interactions, simulating varied teaching scenarios. Incorporating multi-modal interactions (e.g., non-verbal cues) adds depth to the simulations, providing teachers with richer experiences.

3.7.3. Feedback Engine

The Feedback Engine delivers real-time suggestions from mentor agents during simulations, analyzing teacher performance and classroom dynamics. Post-session reports highlight strengths and areas for improvement. Adaptive feedback loops tailor advice based on the teacher's progress and ensure that feedback evolves as teachers refine their skills.

3.7.4. Performance Dashboard

The Performance Dashboard aggregates key metrics, such as student performance, interaction quality, and session progress, allowing teachers to track their development

over time. Adding predictive analytics can offer targeted suggestions for future practice, enhancing personalized learning paths.

3.7.5. Integration of Real-World Data

The platform allows the integration of real-world classroom data to create simulations that reflect actual teaching challenges. These data can include student demographics, attendance, or past performance, enabling more realistic scenarios.

3.7.6. Scalability and Accessibility

The architecture is designed for scalability and accessibility, ensuring compatibility across different educational settings. Cloud-based infrastructure and multi-language support make the platform adaptable for diverse regions, while offline functionality ensures usability in areas with limited connectivity.

4. Use Case

We present a use case scenario to demonstrate the capabilities and practical application of the proposed AI-based platform. This example simulates a teaching session for a history lesson, focusing on examples of classroom interaction, student dynamics, and mentors' feedback. The goal is to illustrate how the platform supports teachers in honing their skills by interacting with virtual students and receiving tailored, real-time feedback from AI-driven mentor agents. In this use case, a history teacher is tasked with delivering a lesson on the causes of World War I. The teacher aims to engage the class in discussing key historical events while navigating student questions and maintaining classroom engagement.

4.1. Student Agents: Simulating Realistic Classroom Dynamics

In this use-case, the teacher interacts with four distinct LLM-driven student agents, each representing a different personality type, learning difficulty, and prior knowledge (Table 3). These agents are designed to simulate the diverse challenges teachers face in real classrooms based on predefined student profiles. The number of virtual students could be easily changed. Default personality features, age, gender, and other traits are randomly chosen for each student, and could be changed by the user by invoking the configuration interface.

Table 3. Examples of virtual students' profiles (personas).

Name	Age	Grade	Behavior in Class	Learning Challenges/Strengths
Emily Chen	17	11	Participates quickly in class discussions	Sometimes struggles to stay focused on one topic
Michael Johnson	16	11	Often engages with follow-up questions to clarify understanding	Finds it challenging to retain specific facts
Sophia Rogers	16	11	Detail-oriented, focused on task completion	Requires more time to process and answer complex questions
David Rodriguez	17	11	Shows strong engagement in analytical thinking	Faces challenges understanding complicated language and historical terms (ESL student).

These virtual students respond to the teacher's prompts, ask clarifying questions, and showcase learning difficulties, providing the teacher with diverse classroom scenarios. The simulation allows the teacher to practice adjusting their teaching methods based on individual student needs, repeating lessons if necessary, and refining explanations for better comprehension.

4.2. Class Interaction and Engagement

The lesson begins with the teacher posing a question about the causes of World War I (Figure 2). Emily Chen, who tends to participate quickly in class discussions, immediately responds by mentioning the assassination of Archduke Franz Ferdinand. While her response is accurate, it lacks the depth and additional context that could help deepen the class discussion. The teacher recognizes Emily's tendency to jump in quickly and praises her for identifying the event but moves the discussion forward to maintain her engagement and prevent her from losing focus.

Teacher: Good morning, class! Today, we'll be discussing the causes of World War I. Who can name one of the significant factors that led to the war?

Emily Chen: The assassination of Archduke Franz Ferdinand of Austria-Hungary in 1914.

Teacher: Excellent, Emily! That's often considered the immediate trigger for the war. Can anyone else name another factor?

Michael Johnson: Wasn't there also tension between European countries due to imperialism and militarism?

Teacher: Great point, Michael. Imperialism and militarism were indeed major contributing factors. Let's discuss how these elements created a volatile situation in Europe.

Figure 2. Sample of class interaction.

Michael Johnson, who often struggles with retaining specific facts, follows up with a broader observation about imperialism and militarism contributing to tensions in Europe. Despite his challenge with memory recall, Michael often engages with clarifying questions to ensure he understands the material. In this case, he asks for more details to connect the concepts of imperialism and militarism to the causes of World War I. The teacher, recognizing Michael's need for repetition, reinforces the key points by restating the events in a clear, structured manner. This repetition helps Michael solidify his understanding and aids his retention of the details. The above interaction is summarized in Figures 2 and 3.

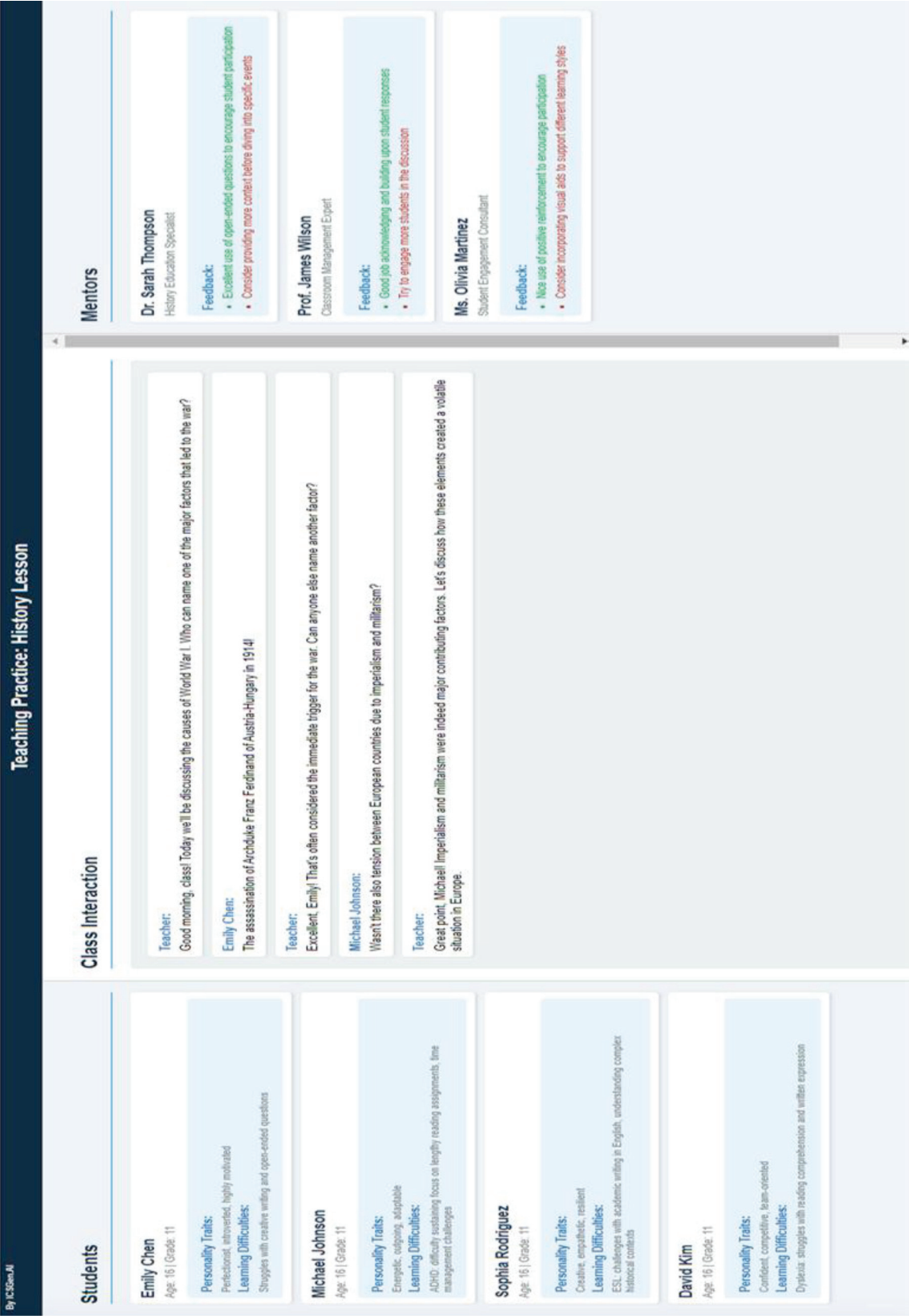


Figure 3. History teaching practice simulation example demonstrating the proposed virtual class.

The screen in Figure 3 is divided into three primary regions, each serving a distinct function. The left region of the screen displays a list of virtual students, randomly and arbitrarily developed by the generative system. The students are presented in boxes, which include randomly chosen names like “Emily Chen”, “Michael Johnson”, and so on. Each student was randomly assigned visible attributes, such as age, grade level, and personality traits, with brief descriptions under their names. The central section consists of a large area showing the ongoing dialogue between the teacher and the students, represented as a chat or transcript. Here, the teacher’s prompts to the virtual students and their responses are shown in real time, along with the teacher’s follow-up prompts and questions. On the right side of the screen are three virtual mentors. These are generated agents labeled as individuals with specialized areas of expertise, such as Dr. Sarah Thompson or Prof. James Wilson. Here, the mentors provide feedback on the teacher’s actions, using text-based comments and suggestions that appear beside their names. This layout allows the user to view the interactions among the teacher, students, and mentors simultaneously.

4.3. Mentor Agents: Providing Real-Time Feedback

Throughout the use case lesson, three AI-driven mentor agents observe the class interaction and offer real-time feedback to the teacher. The mentor information and feedback are summarized in Table 4. For example, after the teacher’s interaction with Michael Johnson, Dr. Sarah Thompson suggests emphasizing key historical events more explicitly to aid in memory retention. Prof. James Wilson recommends asking more open-ended questions to deepen classroom discussion. At the same time, Ms. Olivia Martínez suggests using more straightforward, more direct language to engage students like David more effectively.

Table 4. Mentors’ profiles and feedback.

Mentor’s Name	Expertise		Feedback
Dr. Sarah Thompson	History Education Specialist	Strengths	Excellent use of open-ended questions to encourage student participation
		Suggestions	Consider providing more context before diving into specific events
Prof. James Wilson	Pedagogical Expert	Strengths	Good job acknowledging and building upon students’ responses
		Suggestions	Try to engage more students in the discussion
Ms. Olivia Martínez	Student Engagement Consultant	Strengths	Excellent use of positive reinforcement to encourage participation
		Suggestions	Consider incorporating visual aids to support different learning styles

4.4. Teaching Performance Evaluation and Feedback

After the simulated lesson, the platform generates a performance summary based on the student agents' interaction logs and the feedback from mentor agents. This summary highlights areas of strength, such as the teacher's ability to simplify complex topics for students with language difficulties, and areas for improvement, such as providing clearer instructions to engage more reserved students. Clearly, using virtual students prevents the possibility of measuring the learning achievements of real students. So, if rigorous validation is sought, some observations on the achievements of real students are necessary. However, only a small sample may suffice for statistical validation.

Measuring teacher performance can involve analyzing class interaction transcripts through large language models (LLMs) and natural language processing (NLP) to extract quantifiable features that serve as proxies or indicators of teacher efficacy. Although these features are not exhaustive, as true efficacy encompasses more than can be inferred from discourse alone, they offer valuable insights into classroom dynamics. One dimension of analysis is the teacher–student talk ratio, in which the percentage of teacher talk relative to student talk can reveal the balance between lecturing and interactive dialogue. Turn-taking analysis further refines this assessment by determining whether a single speaker, usually the teacher, dominates the conversation or whether verbal contributions are more evenly distributed among participants.

Questioning techniques, a crucial element in effective instruction, can be gauged by tracking the frequency and types of questions posed. Open-ended, reflective, or evaluative questions generally promote deeper thinking compared to yes/no or recall-based queries. The average wait time after posing a question offers additional insight; a longer pause can encourage more meaningful student responses. Feedback patterns also influence the classroom climate and learning outcomes. The ratio of positive to corrective feedback sheds light on how often teachers provide encouragement and validation relative to criticism. The depth of feedback—whether it is specific, constructive, and linked to lesson goals or merely cursory—offers a further indicator of the teacher's ability to guide and support student learning.

Instructional clarity and structure can be investigated by measuring discourse coherence, which reflects how well the teacher organizes ideas, transitions between concepts, and maintains topical consistency. High coherence often indicates effective instructional methods. A related aspect is the use of scaffolding: markers of teacher scaffolding—such as guiding cues, prompts, or leading questions—demonstrate a commitment to building on student responses and facilitating deeper understanding. Student engagement indicators, for example, the proportion of student-initiated talk, serve as a gauge of how comfortable and motivated students feel to participate without being prompted. Additionally, the sentiment analysis of student contributions can highlight whether students exhibit a generally positive or engaged emotional tone, a factor that may correlate with a supportive classroom environment.

Vocabulary and complexity, in terms of the teacher's lexical diversity, can signal expertise and the capacity to contextualize course content. Aligning language with accurate, domain-specific terminology can be especially critical in subjects like mathematics or the natural sciences. Another domain of interest is response sensitivity and adaptation, demonstrated when teachers modify their explanations or questions based on student statements, suggesting responsiveness and an adaptive teaching style. Intertextual references, such as referring back to earlier lessons or linking new content to prior student contributions, can further reflect attentiveness to student input and continuity in instruction.

Emotional and motivational support, measured by the frequency of encouraging language or empathetic remarks, provides an indication of how well a teacher fosters a positive learning atmosphere. Personalizing feedback by using students' names or tailoring guidance to individual needs can reinforce this supportive environment. Additionally, time on task and lesson flow can be assessed by examining how smoothly the teacher transitions between activities, as well as how quickly off-topic discussions are redirected to instructional goals.

Finally, reflective talk represents a teacher's self-awareness and adaptability. Instances where the teacher explicitly explains their thought process or revises instructional methods in real time—signaled by statements such as “Let's approach this another way...”—can indicate a high level of pedagogical awareness and continuous professional growth. By analyzing these various dimensions in class interaction transcripts, researchers and practitioners can develop a more nuanced understanding of teacher performance, even though the broader concept of teacher efficacy necessarily extends beyond any single set of measurable linguistic features.

LLMs and NLP can support these metrics in several ways. First, advanced speech-to-text and segmentation models automatically transcribe spoken language and divide transcripts into speaker turns, facilitating the calculation of talk ratios and turn-taking patterns. Second, NLP models classify questions according to frameworks like Bloom's Taxonomy, distinguishing, for example, between open-ended and closed questions. Third, sentiment and emotion analysis—powered by LLM-based classifiers—gauges the tone of teacher feedback and student responses, providing insight into the classroom climate. Fourth, topic modeling and discourse analysis identify the main themes or topics under discussion, track how long each topic persists, and evaluate the coherence of the teacher's instruction. Fifth, named-entity recognition (NER) detects references to student names, academic terms, or personalizing language, serving as indicators of student-centered instruction. Lastly, by comparing initial teacher statements to subsequent modifications, NLP can quantify the teacher's responsiveness to student input or misconceptions, thus offering a measure of adaptive teaching. Figure 4 shows a sample teacher efficacy report based on the above descriptions.

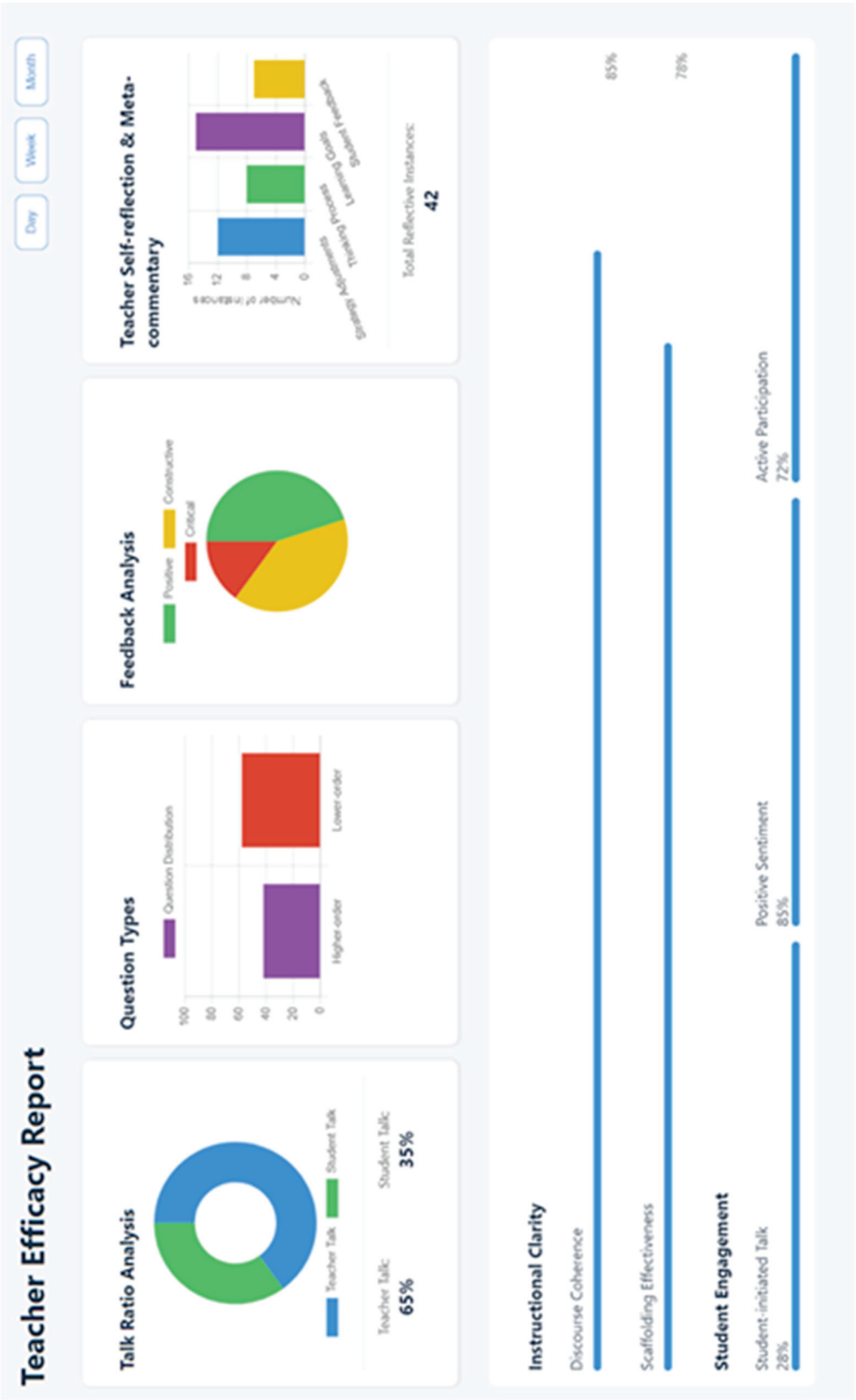


Figure 4. Teacher efficacy report.

5. Discussion

The proposed AI-driven teacher training framework offers a novel approach addressing the challenges of scalability, personalization, and adaptability in teacher education (in comparable teacher training platforms). This platform uses large language models (LLMs) and multiagent systems to provide a flexible solution for developing teaching competencies through deliberate, repeated practice. The system creates realistic, dynamic classroom simulations, allowing teachers to interact with adaptive virtual student agents and receive real-time feedback from AI-powered mentor agents.

One of the framework's key advantages is its ability to simulate diverse classroom dynamics. The platform's LLM-driven student agents can be customized with varying learning styles, cognitive abilities, and behavioral traits. These student agents offer teachers a highly realistic and flexible environment. These agents adapt based on the teacher's instructional methods, evolving to reflect student growth, regression, and various individual needs. This adaptability mirrors real-world challenges where teachers must adjust their strategies in response to diverse classroom conditions, providing a valuable practice ground for developing classroom management and differentiated instruction skills.

In the use case, the history lesson on World War I demonstrates the framework's ability to offer a rich, varied teaching experience. Here, the teacher interacts with student agents representing different learning profiles, such as language barriers and attention difficulties. The platform's adaptability is further exemplified when the teacher tailors their approach based on real-time student feedback—adjusting explanations and pacing to suit individual student needs. Mentor agents provide multi-dimensional feedback on these interactions, offering guidance not only on lesson clarity and engagement but also on deeper aspects such as managing classroom dynamics and responding to student challenges.

The platform's use of real-time, personalized feedback is a notable advantage over traditional teacher training methods. Mentor agents continuously assess the teacher's performance, delivering insights that are tailored to specific teaching scenarios. This iterative cycle of practice, feedback, and improvement is essential for developing effective teaching strategies and enhancing pedagogical skills. By focusing on both instructional techniques and classroom management, the platform supports comprehensive teacher development in a controlled environment that minimizes risks for actual students.

While the framework presents significant advantages, it also faces challenges that must be addressed to maximize its potential fully. One key issue is ensuring the realism of virtual student agents. Although the platform simulates diverse learning needs, it may struggle to replicate the emotional, cultural, and socio-economic complexities that exist in real classrooms. Enhancing the emotional intelligence of virtual agents would improve the authenticity of the simulations, allowing teachers to better practice while addressing the nuanced, interpersonal aspects of teaching.

Another concern is the quality and depth of AI-generated feedback. While the AI system provides data-driven insights quickly, it risks focusing too much on quantifiable elements like pacing and content delivery, potentially overlooking more subtle classroom dynamics such as student engagement and relational interactions. Ensuring that AI feedback complements rather than replacing human mentorship is crucial for fostering reflective, holistic teaching practices.

Additionally, ethical considerations regarding AI bias and data privacy are paramount. Biases in AI-driven feedback or student simulations could inadvertently reinforce harmful stereotypes, affecting both teacher and student development. Addressing these issues will require robust ethical frameworks to guide the responsible deployment of AI in education, ensuring that the system promotes fairness, transparency, and inclusivity.

Since technology mediates how people interact with the world around them and understand it, the very use of technology by itself is a factor that influences the beliefs and values, and hence the actions, of the human agents involved. Therefore, we advocate that using simulation for teacher training should be accompanied by training on real classes with real human students. This would help mitigate the biases in beliefs and values of beginning teachers who have been developed through 10,000 h of generative AI simulation-based training. However, we still are in the dark as to how technology-based training will affect the teachers in the classrooms they are assigned to teach. How would this change how classrooms are managed and how students are taught, and what further downstream impacts would this have on future generations?

Despite these challenges, the framework's advantages are substantial. It provides a scalable, accessible platform that supports teachers in refining their skills through deliberate practice in a low-risk, controlled environment. The combination of real-time AI feedback with adaptive simulations offers a level of personalization and responsiveness that traditional training methods cannot achieve. By enabling teachers to engage with diverse, evolving classroom scenarios, the platform fosters the development of critical competencies needed to succeed in today's complex educational environments.

6. Conclusions

The proposed AI-driven teacher training framework offers a scalable and adaptive solution for enhancing teacher education through personalized simulations and utilizing large language models (LLMs) and multiagent systems. The platform simulates diverse classroom environments, enabling teachers to practice with virtual students and receive real-time feedback from AI-driven mentor agents. This approach addresses key challenges in traditional teacher training, such as scalability and the need for repeated, personalized practice and continuous feedback.

The framework supports deliberate practice, with adaptive student agents created using broad theoretical foundations of various learning styles and personalities. The student agents evolve based on teacher interactions, helping educators manage diverse student needs. Mentor agents provide multi-dimensional feedback, allowing teachers to refine their instructional strategies and classroom management skills. A use case demonstrates the platform's flexibility in simulating various teaching scenarios, promoting the development of differentiated instruction and classroom engagement. By aligning these capabilities with the study's objectives, this framework directly contributes to addressing the need for scalable, adaptive, and feedback-driven teacher training. The results indicate that AI-driven simulations provide a structured, iterative environment where teachers can improve instructional techniques while adapting to diverse classroom dynamics. Additionally, the incorporation of mentor agents facilitates real-time assessment, ensuring that teachers receive actionable insights to refine their pedagogical approaches. These findings validate the potential of generative AI to enhance professional development in education, bridging the gap between traditional training methods and the evolving demands of modern classrooms.

However, challenges remain, such as ensuring the realism of virtual agents, maintaining the quality of AI feedback, and addressing ethical concerns like data privacy and AI bias. While this study establishes a conceptual foundation, further validation through empirical classroom studies will be essential to fully assess the effectiveness of AI-driven teacher training. Future implementations should explore how real-world educators interact with the platform, measuring improvements in instructional efficacy, engagement, and learning outcomes. Despite these limitations, the platform can potentially transform teacher training by offering scalable, data-driven insights that complement human mentorship.

The development of AI-based simulation platforms for teacher education intersects with core ethical and philosophical issues in pedagogy, raising questions about the nature of teaching, learning, and the role of technology in education. One fundamental dilemma is the tension between standardization and individuality in pedagogy. While AI platforms can provide consistent, scalable training experiences, they risk oversimplifying the complex, context-dependent nature of teaching, which often requires adaptability and empathy (Bartholomay, 2022; Dunn & Larson, 2023). This aligns with the philosophical debate over whether education should focus on measurable outcomes or the holistic development of students, a concern highlighted by Miseliunaite et al. (2022) in their critique of technocratic approaches to education. Additionally, using AI in teacher training raises ethical concerns about data privacy and surveillance, as fine-tuning LLMs on class transcripts or student interactions may inadvertently expose sensitive information (Selwyn, 2019).

Furthermore, the reliance on AI simulations may devalue the irreplaceable human elements of teaching, such as moral guidance and emotional connection, which are central to the pedagogical philosophy of thinkers like Freire (2020), who emphasized the importance of dialogue and critical consciousness in education. To address these issues, AI-based platforms must be designed with ethical frameworks that prioritize transparency, inclusivity, and respect for the human dimensions of teaching. By engaging with these philosophical and moral dilemmas, educators and developers can ensure that AI tools complement, rather than undermine, the core values of pedagogy.

Future research should focus on assessing the long-term impact of AI-driven training on teacher performance, improving the emotional intelligence of AI agents, and developing ethical frameworks to guide the responsible use of AI in education. Empirical studies should explore how teachers engage with AI-driven simulations in practice, evaluating both skill acquisition and transferability to real classroom settings. Additionally, interdisciplinary collaboration between AI researchers, education experts, and policymakers will be crucial in refining the framework for widespread implementation. This framework could significantly enhance the quality and accessibility of teacher training. It provides scalability and satisfies the need for repeated, personalized practice and continuous feedback. The proposed framework ensures that educators are better prepared to meet the complexities of real-world classrooms.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
GPT	Generative Pretrained Transformer
LLM	Large Language Model
MBTI	Myers–Briggs Type Indicator
TALIS	Teaching and Learning International Survey

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