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Enhancing digital competency in EFL teacher education: Investigating graduate-level student teacher's design and implementation of digital materials

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Abstract

In modern educational technology, the digital competencies necessary for effective English language instruction remain relatively unexplored. This research addresses this knowledge gap by examining a graduate-level course designed to prepare prospective EFL student teachers with the essential skills to create digital teaching resources. Grounded in the SAMR framework, this investigation aims to introduce a new pedagogical design reflecting the progression of digital evolution. The primary goal is to determine the overall effectiveness of this structured approach in enhancing graduate students' digital proficiency and instructional capabilities. By utilizing the SAMR model, the study hopes to establish a standard for assessing technology integration in pedagogical training, thereby improving the digital skills of upcoming EFL instructors across diverse technological platforms. The research narrative is presented across two interconnected academic settings: a graduate module emphasizing practical expertise in developing digital assets and a parallel online undergraduate English module for implementing these digital materials. The findings highlighted both the transformative potential of digital tools and the challenges in their adoption, emphasizing the necessity for training that integrates both technical aspects and pedagogical principles. This study provided strategic insights for curriculum developers in teacher education and offered guidance for future English instruction.

Keywords: SAMR framework, Digital competencies, EFL teachers, Teacher education, Curriculum design

Introduction

The rapid digital transformation in education has led to an increased demand for digitally competent teachers. In the English as a Foreign Language (EFL) context, with technology becoming an integral part of teaching and learning, EFL teachers are expected to effectively use digital tools to create interactive and engaging learning experiences for students. However, current research indicates a significant gap in the digital competencies of EFL teachers, suggesting that many teachers feel unprepared to integrate technology meaningfully into their classrooms. This gap highlights the need for teacher training programs that not only introduce technology but also focus on equipping future teachers with the skills to effectively develop and incorporate digital tools into their teaching practice. This study aims to bridge this gap by examining the development of digital competencies among graduate-level EFL student teachers through a specialized training course.

This study explores how a structured approach, based on the Substitution, Augmentation, Modification, and Redefinition (SAMR) framework, can enhance the digital competencies of prospective EFL teachers. The SAMR model provides a hierarchical framework for integrating technology into teaching, allowing educators to progress from the simple substitution of traditional methods to the redefinition of learning tasks through technology. By adopting this model, the study offers insights into the specific digital skills that are critical for modern EFL instruction.

The research unfolds in two interconnected academic settings: a graduate course focusing on practical skills in creating digital materials like video content, electronic handouts, and interactive exercises, and an online undergraduate English course where these digital materials are deployed. This design allows for a focused exploration of our primary research question: "Does specialized training in digital material creation enhance the digital competencies of graduate students, thus preparing them for effective EFL teaching in digitally enhanced settings?" Evidence for this study is gathered through a graduate student self-assessment questionnaire to monitor digital skill development and evaluations from undergraduate students who used these digital materials in their English courses.

This research aims to offer empirical evidence supporting the need for specialized training in digital competencies as a critical aspect of modern English language teacher preparation. Given the pervasive role of technology in contemporary educational settings, the findings of this study are intended to inform future curriculum design and policy decisions within teacher education programs.

Literature review

Language learning is a complex process that involves both stability and change (Ellis & Larsen-Freeman, 2009). Language development is nonlinear, with learners continuously adjusting to their environment and social interactions (Han, 2019). Learning evolves through various influences, and progress unfolds in ways that are often unpredictable (de Bot, 2008; Rosmawati, 2014). To help educators adapt to this complexity, the SAMR model offers a clear framework for using technology in the classroom. This approach helps educators create dynamic, flexible learning environments where technology supports students' evolving needs, fostering the adaptive learning that Dynamic Systems Theory (Hiver et al., 2022) emphasizes. By equipping teachers with these tools, classrooms become better suited to the unpredictable nature of language learning, allowing for more personalized and responsive instruction.

Digital competency in EFL classroom

Digital competency is broadly defined as the skills and knowledge that enable individuals to use digital technology effectively and responsibly (Ferrari, 2013). In the context of education, professional digital competency presents a challenge for educators (Esteve et al., 2020). Lund and Erikson (2016) emphasize that teachers, beyond being proficient in using digital technologies for specific professional tasks, must also foster meaningful and effective technology usage among their students. This is particularly challenging because educators are required to continuously make pedagogical and didactic judgments on how digital technologies can enhance learning opportunities in various subjects (Krumsvik, 2008, 2014).

In the specific context of English as a Foreign Language (EFL) education, digital competency involves integrating technology into course design to enhance language learning experiences (Healey et al., 2019). This integration is aligned with the principles of Computer-Assisted Language Learning (CALL), which promotes the effective use of technology in language education (Cao et al., 2023; Kessler, 2018; Stockwell, 2012). The use of technology in EFL instruction enables a variety of approaches, such as the utilization of videoconferencing tools to facilitate multimodal interaction, which enriches the learning experience in online classrooms (Hampel & Stickler, 2012). Additionally, mobile learning devices offer interactive opportunities that require a re-evaluation of traditional pedagogical approaches to integrate their benefits (Jeng et al., 2010). These approaches suggest that digital competency is not just an auxiliary skill but is integral to effective pedagogy in EFL settings.

Digital competency in EFL teacher training

Despite the growing emphasis on technology-enhanced learning environments, a significant gap exists between the recognition of digital competency's importance and its practical implementation in teacher training programs. Tondeur et al. (2017) observed that "empirical evidence suggests that prospective teachers frequently do not feel sufficiently equipped to integrate technology into their teaching environments seamlessly" (p. 463). Similar findings have been reported by Valtonen et al. (2015) and Gudmundsdottir and Hatlevik (2018), indicating that teacher preparation programs often fail to adequately prepare educators for integrating digital tools effectively.

Elstad and Christophersen (2017) highlight that the inclusion of professional digital competencies in teacher education is frequently confined to isolated segments of the curriculum rather than being consistently implemented across programs. This limited integration raises concerns about the capacity of initial teacher education to address the digital demands of modern classrooms (Koc, 2013; Tondeur et al., 2017). The low level of technology integration in teacher education programs has led researchers like Gudmundsdottir and Hatlevik (2018) and Kim et al. (2013) to question the effectiveness of current approaches, particularly in the EFL domain where maximizing technology's potential is crucial for enhancing language learning experiences.

Recent literature further explores these challenges. Basantes-Andrade et al. (2022) conducted a systematic literature review identifying the basic standards and frameworks for digital competency in higher education teacher training. Their findings highlight the ongoing efforts to establish a coherent set of competencies but also point to the difficulties in the widespread adoption and practical application of these standards. Similarly, Lin et al. (2023) investigated the rural-urban divide in teachers' digital teaching competency, revealing significant disparities that complicate the implementation of digital competency frameworks across diverse educational contexts.

Moreover, Guillén-Gámez et al. (2023) call for a need to assess the digital competency of teachers, reflecting the growing recognition of precise tools to evaluate and enhance teachers' digital skills. Their study reflects the increasing recognition that comprehensive and standardized evaluation methods are essential for bridging the gap between theoretical digital competency frameworks and their practical application in teacher training programs.

These gaps have significant implications for the quality of EFL teaching and learning. If teacher training programs fail to bridge these gaps, they risk producing educators who are ill-equipped to effectively utilize digital tools, thus potentially diminishing the learning experience for their students. This study addresses these concerns by evaluating the effectiveness of a graduate-level training course focused on enhancing digital competencies in prospective EFL teachers. The course's efficacy is measured through self-

assessments by graduate teacher students and evaluations by undergraduates, who review the digital course materials created by the graduate students.

How to evaluate digital competency

Digital competency is increasingly recognized as an essential skill for the modern age. Within the context of EFL teaching, it not only enhances the pedagogical experience but also prepares students for a world that is ever more interconnected and digitalized. The DIGCOMP framework by Punie et al. (2013) was selected for this study because of its comprehensive, structured, and practical approach to assessing digital competency across five core areas: Information, Communication, Content Creation, Safety, and Problem-Solving. This study, however, narrows its focus to three of these areas—Information, Communication, and Content Creation, the areas that are directly tied to language learning objectives and have immediate implications for EFL pedagogy. This study does not cover the area of Safety because the school administration typically handles safety concerns related to technology use, making it less pertinent to the role of individual EFL teachers in the classroom. Likewise, Problem-Solving is not a focus because this study aims to concentrate on competencies that are most directly applicable to the creation and execution of EFL teaching materials and methods, and Problem-Solving skills, while important, can be considered more of a general competency rather than one specific to EFL pedagogy.

DIGCOMP offers a broad range of digital skills, making it particularly suitable for evaluating the diverse competencies required by modern educators. Its widespread recognition and use across various educational systems, particularly in Europe, add to its credibility and adaptability. The framework has been implemented by governments, institutions, and educational organizations across the European Union to standardize and assess digital competencies in both students and educators, ensuring that it can be applied flexibly in different teaching environments. Moreover, the framework is practical and focuses on developing skills that can be immediately applied in the classroom. The dimensions of Information, Communication, and Content Creation directly align with the specific needs of EFL educators, ensuring its relevance for EFL teacher training.

By concentrating on the selected three areas, this study aims to offer EFL programs a framework that closely aligns training with real-world needs and challenges. In doing so, it seeks to make a meaningful contribution to bridging the gap in digital competency implementation. In this study, the three key areas are defined as follows. They can directly relate to six criteria for evaluating an EFL student's ability to create digitalized teaching materials. Each of them directly correlates with two specific criteria grounded in established educational and technological theories, as elaborated below:

Information

Information literacy not only refers to the ability to locate, evaluate, and effectively use information, but it also entails becoming proficient in the tools that make this possible. For EFL teachers, mastering the digital platforms and search engines that enable them to source authentic materials, plan lessons, and stay updated on pedagogical advancements is crucial. Being adept at using these tools enhances teachers' capacity to execute effective EFL instruction and enables them to adapt to a rapidly evolving educational landscape (Kirschner & De Bruyckere, 2017). The criteria of Tool Familiarization and Content Adaptation align well here, focusing on the mastery of digital tools for information literacy and the adaptation of content to meet classroom needs.

Criterion 1: Tool Familiarization: Specifically addresses the digital platforms and tools required for effective information literacy. A qualified language teacher with digital competency can find out about and try a wider range of search techniques and strategies, know how to cross-check and filter information with strategies, and use tools or digital platforms to organize the information (Mishra & Koehler, 2006).

Criterion 2: Content Adaptation: A critical aspect of information literacy involves adapting information to fit the unique needs of the classroom, reflecting theories of differentiated instruction (Tomlinson, 2014).

Communication

Interactive materials facilitate communication between teaching and learning. Within the modern EFL classroom, the advent of digital tools has significantly transformed teacher-student interaction, advancing it to be more dynamic and engaging. Interactive materials serve as a powerful medium for effective communication and pedagogy. These interactive components sustain student engagement and present intricate language learning tasks in a more accessible and engaging format (Chapelle & Sauro, 2017). The potential to understand, design, and utilize these interactive elements is vital for EFL teachers aiming to maximize the benefits of digital communication platforms. The criteria of Interactive Content Creation and Multimodal Integration are directly related, emphasizing the creation of engaging interactive materials and the integration of various communication modes.

Criterion 3: Interactive Content Creation: Directly linked to the communication domain, this criterion is grounded in constructivist learning theories, which highlight the role of engagement and interaction in learning (Mehrvarz et. al., 2021; Vygotsky et al., 1978).

Criterion 4: Multimodal Integration: This corresponds to the need for incorporating different modes of communication, as suggested by the Multimodal Theory of Communication (Kress & van Leeuwen, 2001).

Content creation

Content creation transcends the mere digitization of existing educational materials; it necessitates a deep pedagogical understanding to make these resources both engaging and pedagogically effective (Godwin-Jones, 2018). This means that EFL teachers must go beyond simply converting traditional materials into digital formats. They must thoughtfully integrate multimedia and interactive elements to enrich the learning experience, aligning well with the curricular goals. The criteria of Material Design & Layout and AI Integration fit here, focusing on the thoughtful integration of multimedia elements and the use of AI in content creation, reflecting the importance of design in learning and the intersection of technology and pedagogy.

Criterion 5: Material Design & Layout: Connected to the Content Creation domain, this criterion is rooted in theories emphasizing the importance of design in learning mentioned by Mayer (2001).

Criterion 6: AI Integration: This sophisticated criterion resonates with the ability to utilize AI for content creation, situated within contemporary educational paradigms that emphasize the intersection of technology and pedagogy, as expounded in research like that of Luckin et al. (2016).

In aligning each criterion directly with one of the three critical domains of digital competency, this study offers a coherent and justifiable framework for evaluating digital skills in the realm of EFL teacher education.

SAMR and digitalized training course design

The SAMR model, aligned with the DIGCOMP framework, is employed in this study to address the dynamic and evolving needs of both online educators and students in the digital age. First, the model offers a hierarchical framework that systematically guides the incorporation of technology into pedagogy, ensuring that each e-learning tool selected serves a distinct educational purpose rather than merely adding digital flash (Hamilton et al., 2016; Puentedura, 2006). This is particularly crucial for online teachers tasked with creating diverse digital materials. Second, recognizing that students may initially have limited familiarity with digitalized teaching and learning materials, the SAMR model's incremental stages—from Substitution to Redefinition—facilitate a gradual, step-by-step approach to mastering these technologies. This scaffolding not only makes the learning curve more manageable for students but also systematically enhances their digital competency (Mishra & Koehler, 2006). Given these advantages, the SAMR model serves as a pedagogically sound foundation for designing the graduate course under investigation. The following sections outline how each phase of the SAMR model is operationalized within the course.

Substitution: Digital classroom management

In the Substitution phase, the primary purpose is to transition traditional classroom management tasks, such as scheduling and assignment submissions, into a digital format. This initial step serves as a foundational layer, allowing students to familiarize themselves with the basics of digital platforms without altering the fundamental pedagogical methods being employed.

Augmentation: Enhanced content and interactive assessments

During the Augmentation phase, the focus shifts towards enriching traditional educational methods by incorporating elements like video editing and interactive quizzes. This introduces a layer of dynamic interactivity and immediate feedback into the learning process. The purpose is to make the learning experience more engaging and responsive, building on foundational digital skills.

Modification: Creation of complex interactive learning environments

In the Modification phase, the objective is to enable students to design intricate, interactive educational materials that incorporate various media forms—such as text, audio, video, and games. Students are encouraged to think creatively and critically, linking technological skills with pedagogical strategies. The ultimate goal is to transform students' engagement with content, making learning more participative and experiential.

Redefinition: Advanced content synthesis and cognitive skills development

The Redefinition phase emphasizes the pivotal role of AI-driven tools like ChatGPT in advancing content synthesis. Through the capabilities of artificial intelligence, educators can produce materials that resonate with specific learning outcomes. This AI-augmented content creation facilitates a more effective pedagogical design and empowers students to engage in higher-order cognitive tasks, such as critical analysis and synthesis. With AI at the forefront of content creation, this stage fundamentally alters the educational landscape, paving the way for enriched comprehension and optimized content development.

The three selected dimensions from the DIGCOMP framework—Information, Communication, and Content Creation—align with the progressive stages of the SAMR model. In the Substitution and Augmentation stages, Information and Communication skills are critical for teachers as they begin integrating technology by finding resources and facilitating interaction through digital platforms. As teachers advance to Modification, Content Creation becomes essential, as they start designing and adapting digital materials that significantly transform learning tasks. At the Redefinition stage, these three dimensions work together to enable teachers to create entirely new learning experiences

that were previously impossible without technology, such as interactive, multimedia-based language tasks in the EFL context. This alignment of the dimensions with SAMR's progression provides a theoretical basis for their selection and supports the structured development of digital competencies in this study.

Research questions

This study aims to investigate the effects of specialized training on enhancing digital competencies among graduate-level student teachers, preparing them for the digitally enriched environment of EFL teaching. Central to our investigation are the following specific research questions:

- How does the integration of the SAMR model into specialized training programs influence graduate students' ability to effectively employ digital tools in EFL teaching?
- In what ways do specialized training enhance graduate students' digital competencies, and how do these competencies prepare them for teaching in digitally enhanced EFL settings?

These questions explore how specialized training impacts graduate students' use of digital tools in EFL teaching and their digital competencies, with findings offering insight into how it prepares them for future technology use in their careers.

Methods

Participants

The research involves two interconnected courses, serving different but complementary educational objectives. The primary course is a graduate-level course titled "Rapid e-learning tools application and production." This course is designed to equip future English teachers with the skills to create and implement digitalized teaching and learning materials. The course enrolls 11 graduate students, named "student teachers" afterward, majoring in TESOL (Teaching English to Speakers of Other Languages). As part of the curriculum, these students are tasked with utilizing various e-learning tools to develop diverse types of learning materials intended for use in an undergraduate course, "Tutorial English." All student teachers have provided unanimous consent for their materials and assessments to be utilized for pedagogical and research purposes.

The online "Tutorial English" course serves as the evaluative setting for the materials produced by the student teachers. This online course targets junior and senior undergraduate students from non-English majors. The online course is required for those

who have not passed the university's exit requirement of a B1 (intermediate level) proficiency as outlined by the Common European Framework of Reference (CEFR). Each set of teaching materials designed and produced by a student teacher is evaluated by about 160 undergraduate students who use those materials as part of their learning process in "Tutorial English."

Procedure-course design

The course design is divided into two main components: skill acquisition in the realm of digitalization and a subsequent phase focused on practical implementation and reflection (Figure 1).

Acquisition of digitalization skills

This graduate-level course, "Rapid e-learning tools application and production," is carefully structured to align with the SAMR model, a framework for integrating technology into education in increasingly sophisticated ways (Figure 2). By categorizing the course content into phases that directly correspond to the four levels of SAMR, the course aims to provide a coherent and step-by-step progression for students to master digital competencies and their pedagogical applications.

Phase 1: Substitution Phase (Weeks 1-2): During the Substitution phase, the first building block of the SAMR model, student teachers are introduced to iClass, a platform that serves as a digital stand-in for traditional classroom management tasks. Student teachers familiarize themselves with the basic functionalities, like course scheduling, material uploading, assignment submissions, and quiz evaluation. Although technology at this stage doesn't add new dimensions to teaching, it does help students become accustomed to using digital tools in an educational setting.

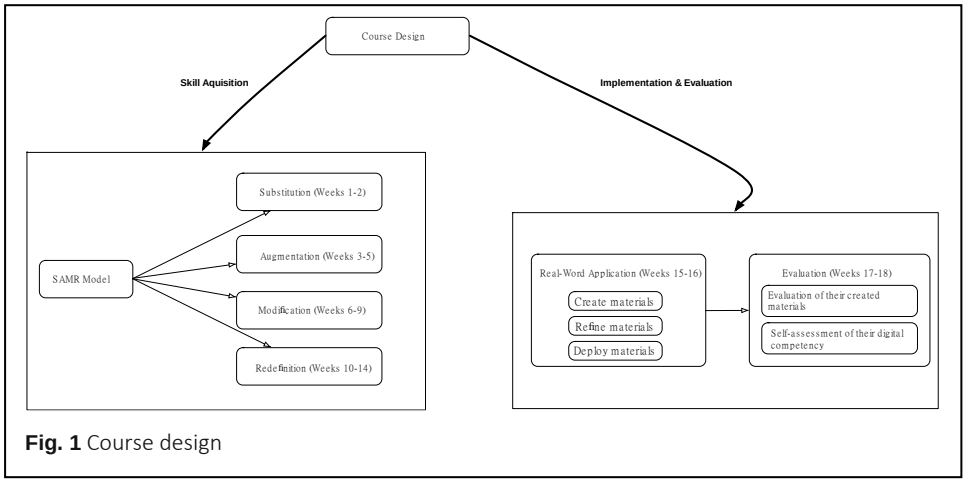

Fig. 1 Course design

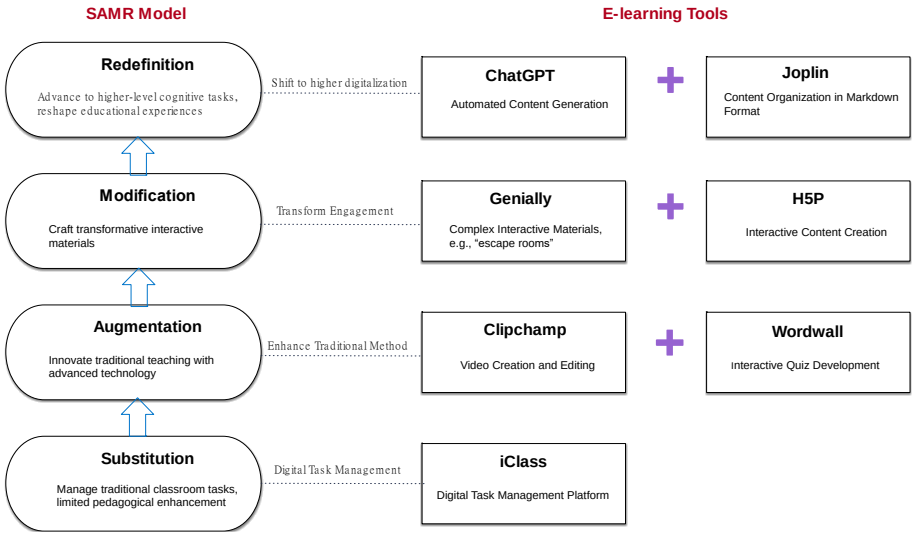

Fig. 2 SAMR model adopted in this study

Phase 2: Augmentation Phase (Weeks 3-5): In the second phase, aligned with the Augmentation level of the SAMR model, student teachers are exposed to Clipchamp and Wordwall, tools that offer more than just a direct substitution. These platforms augment existing teaching methodologies by providing capabilities beyond simple substitution. Clipchamp facilitates video creation and editing, while Wordwall allows for the development of interactive quizzes. These tools augment traditional teaching methods by adding functionalities that enhance the learning experience.

Phase 3: Modification Phase (Weeks 6-9): The course elevates to the Modification level of the SAMR model in this phase, featuring Genially and H5P platforms. These platforms not only replace traditional educational tools but also significantly modify the learning experience. These tools significantly expand the creative scope for student teachers, empowering them to design more complex interactive educational materials. In these interactive environments, student teachers can incorporate a variety of digital materials—texts, audio, videos, and games, altering the ways in which students engage with, and take ownership of, their learning.

Phase 4: Redefinition Phase (Weeks 10-14): At the redefinition level, the focus is on the synergistic combination of ChatGPT and Joplin. ChatGPT excels in generating proficiency-level appropriate articles, enriched with clickable definitions, examples, and grammatical sections. It also provides bilingual translations and generates reading comprehension sections. This rich content is transferred into Joplin, a tool optimized for content organization and presentation. The generated Markdown format from ChatGPT

meshes perfectly with Joplin, creating a smooth transition from content creation to structured presentation. The union of the two combines ChatGPT's content creation strengths with Joplin's organizational capabilities, resulting in sophisticated and targeted electronic handouts. This synergy enables student teachers to focus on higher-level cognitive skills, such as analysis and synthesis.

Implementation and evaluation

After acquiring a comprehensive set of digital skills, student teachers transition to a real-world application stage using "Tutorial English" as the platform for implementation.

Phase 5: Real-World Application (Weeks 15-16): This phase serves as the capstone, allowing student teachers to apply their newly acquired digital skills in a real-world context. Student teachers create pedagogical materials on a subject of their choice, incorporating various multimedia elements, including videos, digital handouts, interactive games, and online tests. All of which undergo thorough review and revision based on instructor feedback. Only materials that meet quality benchmarks proceed to the next stage.

These polished materials are hosted on the iClass platform and shared with undergraduate students enrolled in the "Tutorial English" course. This fusion of technology and pedagogy is vital as the materials become central to the undergraduates' learning experience, offering them a direct engagement with digital pedagogical tools.

Phase 6: Evaluation (Weeks 17-18): The final phase focuses on assessment and reflection. Undergraduates engage with the created materials and offer feedback through an online survey, contributing to the iterative refinement process. Concurrently, student teachers engage in self-assessment, examining their digital competency growth. This evaluation cycle provides a holistic view of the teaching and learning experience, benefiting all participants.

Instruments

The evaluation process adopts a dual-faceted approach to understand the student teachers' digital competencies and the efficacy of their materials. This involves a self-assessment by the student teachers of their digital abilities and an external evaluation by undergraduate students who critically review the materials developed by the student teachers.

While the study employs self-assessments from student teachers to evaluate their development in digital competencies, it also incorporates feedback from undergraduate students who directly used the digital materials created by the student teachers. This dual approach strengthens the validity of the findings. Self-assessments allow the student teachers to reflect on their growth. However, the feedback from undergraduates—who are

the actual users of the digital materials—provides an external and objective perspective on the effectiveness and practicality of these materials in real-world teaching contexts.

Self-assessment of student teachers' digital competency

Student teachers participating in the study will complete a comprehensive self-assessment questionnaire designed to evaluate their digital competency. The self-assessment tool aims to facilitate student teachers' introspection into their digital competencies. In line with the DIGCOMP study by Punie et al. (2013) focusing on Information, Communication, and Content Creation, the evaluation instrument encompasses six criteria evaluated through a 1-10 Likert scale. Furthermore, we gathered text-based reflections from student teachers to delve into their thought processes.

- *Tool Familiarization (Understanding tool functionalities and applications):* This criterion focuses on the EFL teachers' proficiency in utilizing digital platforms and search engines essential for sourcing educational content and staying current with pedagogical trends, emphasizing the vital role of technology in modern education. This aligns with the DIGCOMP area of Information by emphasizing the skills required for effective information management.
- *Interactive Content Creation (Creating engaging, interactive learning materials):* This criterion highlights the importance of designing engaging, interactive materials that facilitate active learning and participation, underlining the transformative impact of digital tools on teacher-student interaction within EFL classrooms. This criterion aligns with the DIGCOMP area of Communication by promoting meaningful and dynamic learner interactions.
- *Multimodal Integration (Integrating text, images, audio, video):* This criterion involves the strategic combination of text, images, audio, and video to create rich, immersive learning experiences, reflecting the diverse ways information can be communicated and understood in digital environments. This aligns with the DIGCOMP area of Communication, as it deals with combining different modes of expression and communication.
- *Material Design & Layout (Creating aesthetically pleasing and user-friendly designs):* The criterion refers to the development of educational resources that are not only informative but also aesthetically pleasing and user-friendly, ensuring materials are accessible and engaging for learners. This criterion aligns with the DIGCOMP area of Content Creation, focusing on the aesthetic and functional design of digital resources.
- *Content Adaptation (Adapting content for different learning styles, needs, levels):* This criterion focuses on producing digital course content to accommodate various learning styles, needs, and levels, highlighting the flexibility and adaptability

required in digital education to meet diverse learner demands. This criterion aligns with the DIGCOMP area of Information by emphasizing adaptability in the presentation and application of information.

- *AI Integration (Incorporating AI tools, e.g., ChatGPT, to enhance learning):* This criterion explores the innovative use of AI tools, such as ChatGPT, to enhance instructional materials and learning outcomes, showcasing the cutting-edge intersection of technology and pedagogy in content creation. This criterion aligns with the DIGCOMP area of Content Creation, as it involves the innovative use of technology to enrich educational content.

Assessment of digital learning materials created by graduate students and their impact on undergraduate students' learning

The other objective of this study was to assess the effectiveness of digital learning materials developed by student teachers in supporting undergraduate education. This assessment gathered feedback from undergraduate students who utilized these materials. The aim was to ascertain whether student teachers' proficient digital design had a noticeable impact on the self-perceived learning outcomes of undergraduates. When evaluating the results of any undertaking, it is essential to establish a precise definition of what qualifies as a significant outcome, as underscored by Biggs and Collis (1982). In developing digital learning materials, this significant outcome can be measured by the self-perceived satisfaction and improvements in users' abilities after engaging with the digital materials, as Illeris (2002) recommended. The undergraduate students were tasked with evaluating the effectiveness of the designed digital materials created by the student teachers. Each set of materials prepared by a student teacher will be assessed by 160 undergraduate students who utilize the materials for their learning. The evaluation instrument will contain four Likert-scale items. The original evaluation form was proposed in Mandarin Chinese; here are the translated items:

- Overall satisfaction with this unit: (Rate from 1-5)
- Satisfaction with the digital video in this unit: (Rate from 1-5)
- Satisfaction with the interactive materials in this unit: (Rate from 1-5)
- The design of this unit helped you gain useful knowledge: (Rate from 1-5)

This dual-faceted evaluation, from users (undergraduates) and designers (student teachers), offers a comprehensive lens into student teachers' digital competencies, intertwining introspective self-assessment with practical feedback. It reinforces the importance of not just understanding, but also effectively applying digital tools in educational contexts, paving the way for education in the digital era.

Results

The study's results are structured into three sections, providing a comprehensive view of student teachers' digital competency. The presentation begins with the materials designed and created by the student teachers, showcasing their progression across each phase of the SAMR model. This is followed by analyzing the self-assessment responses, highlighting the student teachers' perceptions of their digital competencies. To round off this section, feedback from undergraduate evaluations is presented, offering insights from the end-users and their interactions with the digital materials. Through this three-tiered approach, the study captures both the tangible and perceived growth in digital competency among these student teachers.

RQ1: Student teachers' progress in the SAMR model

Substitution and augmentation

During the substitution phase, student teachers focused on comprehending the functionalities and management of iClass, the course management system. Here, they uploaded materials and quizzes carefully structured to ensure students navigated through a specific learning order. The objective was to encourage a sequential progression, discouraging students from bypassing or selecting content out of sequence. In essence, iClass served as a direct digital counterpart to traditional teaching methods without significant modifications (Figure 3).

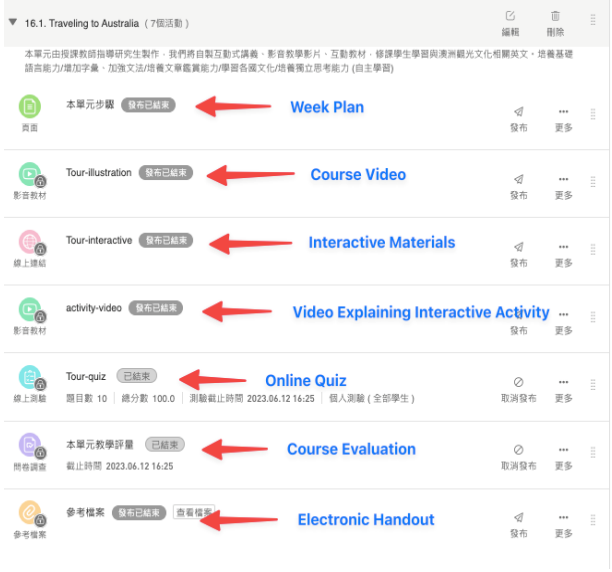

Fig. 3 One-week learning materials in iClass

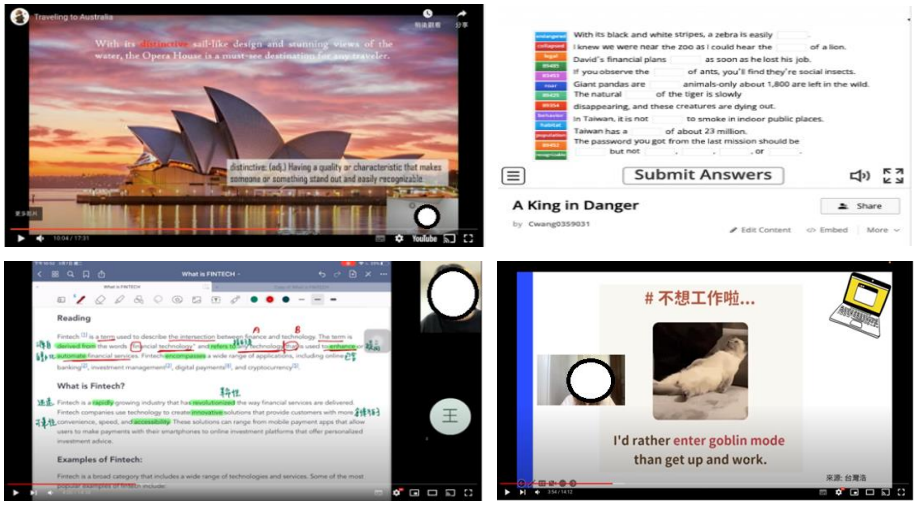

Fig. 4 Student's illustrative videos and Wordwall exercise

As the transition to the augmentation phase commenced, there was a marked advancement in technological integration. Student teachers began exploring video creation to enhance content delivery. Concurrently, tools like Wordwall were utilized for online gaming evaluations, transforming assessments into engaging, interactive experiences (Figure 4).

Modification

The modification phase led to a paradigm shift towards revising traditional teaching methodologies by introducing comprehensive multimedia elements (Figure 5). In this phase, student teachers employed interactive platforms to blend video, audio, games, and

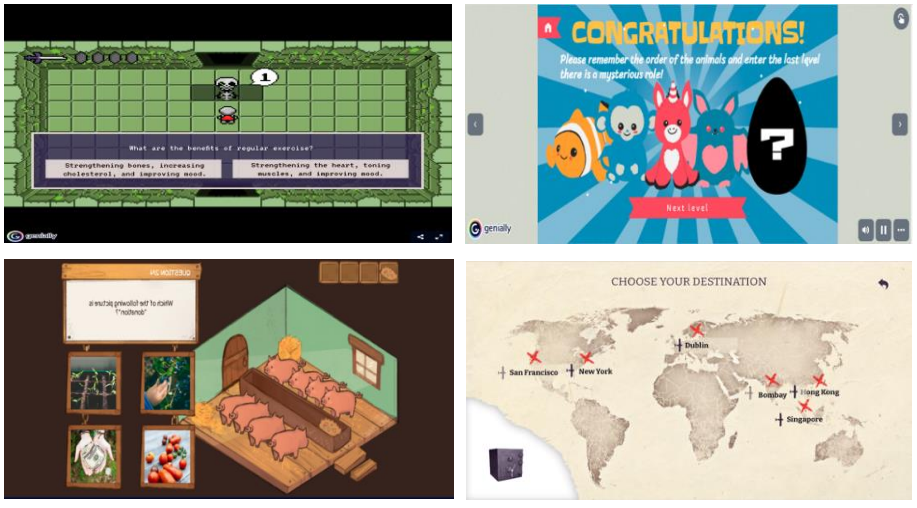

Fig. 5 Student's interactive materials

text, creating robust learning materials. This diverse approach catered to varied learning styles and was highlighted by dynamic elements such as clickable buttons, animations, and interactive infographics. Beyond mere aesthetics, these features catalyzed active learner engagement, inviting deeper content exploration. The multimedia integration in this phase redefined educational horizons, pushing past the confines of conventional teaching.

Redefinition

The redefinition phase witnessed student teachers innovatively combining ChatGPT and Markdown to craft interactive educational handouts. ChatGPT's capabilities surpassed standard teaching paradigms, enabling the auto-generation of articles according to students' comprehension levels. Additionally, it offered instant translations, promoting multilingual accessibility. Further features, like vocabulary definitions, examples, and proficiency in grammar analysis and reading comprehension question generation, emphasized its versatility. Alongside this, Markdown was used to turn the generated content into interactive handouts. With its straightforward markup language, student teachers added clickable elements and other interactive features, making the learning materials more hands-on for students.

The student teachers offered a renewed perspective on education by combining ChatGPT's advanced content generation with Markdown's interactive formatting. The fusion of ChatGPT's content adaptability with Markdown syntax signaled a groundbreaking path in course design. Here, student teachers transitioned to active designers, utilizing AI tools to reconstruct course layouts and delivery methods. This transformation emphasizes the vast possibilities of technology in evolving pedagogical strategies, moving beyond traditional boundaries to offer a more adaptive learning experience.

Subsequent images provide glimpses into a student teacher's digital handout, exemplifying the synergy between ChatGPT and Markdown. Every content is an outcome of ChatGPT's capabilities, refined further by Markdown as suggested by ChatGPT. This phase requires student teachers to utilize AI, generating exhaustive handouts without manual intervention.

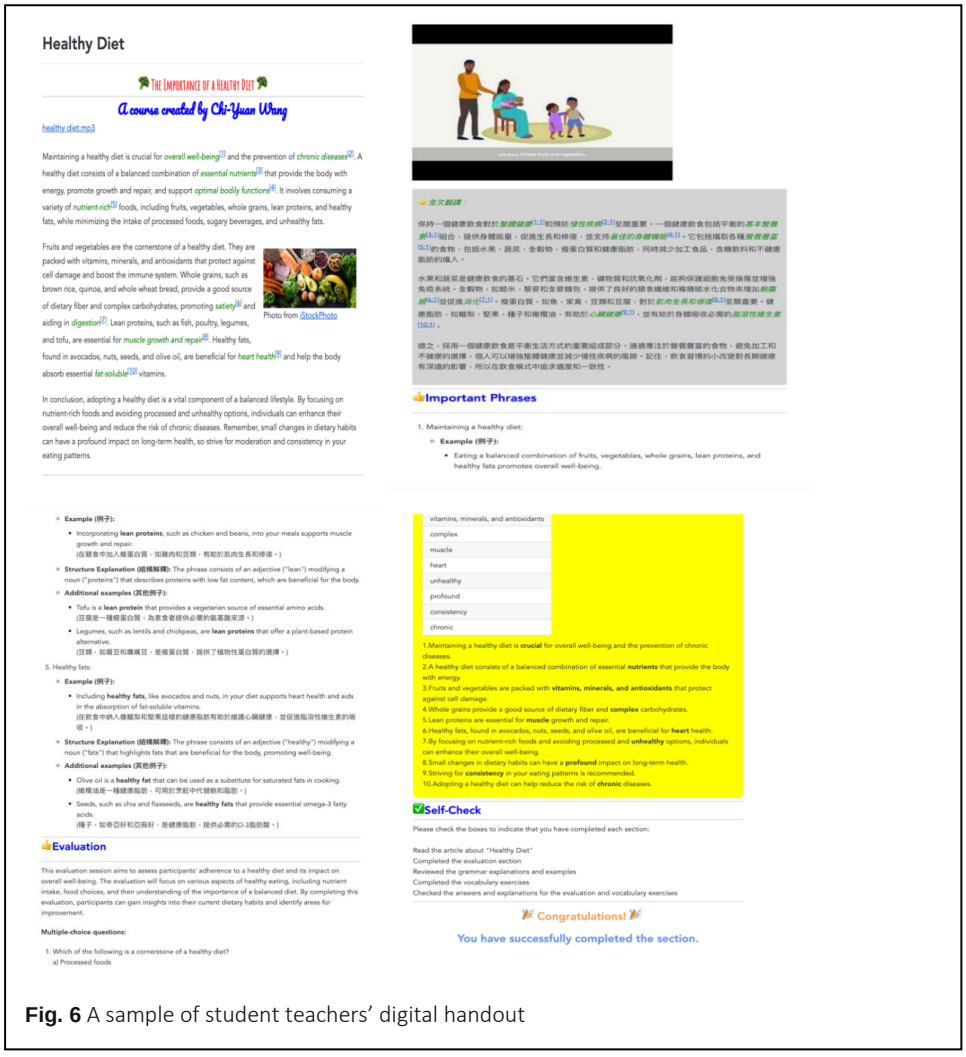

Fig. 6 A sample of student teachers' digital handout

RQ2: Student teachers' growth in digital competency

Student teachers' self-assessment

- ***Prior digital familiarity***

Upon inquiry about their initial familiarity with crafting digital materials, a pronounced majority revealed a scanty experience. Merely 2 out of 11 student teachers had hands-on experience with tools, including video creation, Kahoot!, Padlet, Jamboard, H5P, and Genially. One of them had participated in the researcher's other course, which focused on linguistics' digitalization (Table 1). This result emphasizes the fresh slate with which most student teachers started, underscoring their transformative journey during the course.

Table 1 Student teachers' past digital experiences

Students	Describe your experiences of creating and using digitalized materials
Student 1	Not very much!
Student 2	No
Student 3	No
Student 4	No
Student 5	No experience at all.
Student 6	I created my own YouTube channel during pandemic lockdown and started to produce videos since then. Other than that, I apply Wordwall, padlet, Kahoot into my online teaching at times.
Student 7	Kahoot, genially, h5p, Microsoft office, padlet, jamboard
Student 8	I seldom use the digitalized materials to design a course. For me, that is an unexplored area.
Student 9	Before taking this course, I had limited exposure to digital resources, and I wasn't very interested in them. I used to think that traditional, structured teaching was sufficient.
Student 10	To present in a basic format, like Microsoft or PDF.
Student 11	Hard!

Despite slight differences in prior experience, we chose to discuss the student teachers together to focus on their collective growth. Dividing them would detract from the study's aim of highlighting the overall transformative journey, especially since most students began with similarly limited digital experience. Additionally, with only 11 students participating, dividing them into smaller groups would result in sample sizes that are too small to be representative or provide meaningful insights applicable to broader educational contexts.

- ***Digital competency evaluation***

In response to their self-evaluation on digital competency spanning six distinct criteria, two student teachers indicated no discernible progress in most areas of the digital competency criteria. Among them, one student teacher, despite her overall static feedback, pointed out a specific area of growth—AI integration, a sector towards which she had previously displayed indifference. She noted, "I realized I'm better at using AI tools for lessons than I thought. I didn't think it was that important before," highlighting a shift in her attitude towards AI integration despite initial indifference. On the other hand, the remaining 9 student teachers witnessed substantial growth over the semester's duration. This was not just an incremental change—it signified a deepened understanding, a more detailed understanding of digital methodologies, and a more substantial capability to integrate technology into their practices. Their feedback highlighted more than just a slight shift in competency. Instead, the change was profound—it represented a transition from rudimentary knowledge levels to a more advanced comprehension of digital tools. This shift suggested that student teachers weren't merely adding a few more digital skills to their repertoire, but they were reshaping their entire understanding and approach towards the integration of technology in their work (Table 2).

Table 2 Student teachers' self-perceived improvement on digital tools

Criteria / Students	Tool Familiarization	Interactive Content Creation	Multimodal Integration	Material Design & Layout	Content Adaptation	AI Integration
S1	5→8	5→8	5→8	5→8	5→8	5→8
S2	5→8	4→7	4→8	4→8	4→6	3→7
S3	4→8	4→8	4→8	4→8	4→8	4→8
S4	6→7	6→6	5→5	5→5	5→5	5→7
S5	2→8	1→8	2→8	2→8	2→8	2→9
S6	3→7	3→8	3→7	3→7	3→7	3→8
S7	6→8	4→6	5→7	5→7	5→6	3→7
S8	4→8	4→9	2→8	2→8	2→7	5→9
S9	2→9	1→9	2→9	2→9	1→9	1→8
S10	4→7	4→7	3→6	3→6	4→7	4→7
S11	8→8	8→8	8→8	8→8	8→8	8→8

- ***Reflective insights***

The student teachers' reflections offer a profound testament to their transformative learning journey, beginning with an initial lack of awareness about digital material design and evolving into a deep appreciation for the role of digital resources in education. This transformation highlights the course's impact on their understanding and application of digital tools in English teaching, from discovering new online resources to familiarizing themselves with advanced technologies like AI. Along the way, they faced challenges but emerged with enhanced digital tool proficiency and renewed pedagogical strategies, marking a significant shift in their educational approach.

One student teacher recalled her initial phase: "Before taking this course, I was oblivious to digital material design. This was partly because my own education rarely integrated digital materials." This initial stance transformed post-course, as she discerned the pivotal role digital resources play in fostering a more engaged and efficient learning process, emphasizing, "I realized the potential of digital materials in making learning more engaging and efficient." Her reflection reveals an educational reality where integrating digital materials isn't the norm. The evolution in her understanding post-course, however, underscores the course's ability not just to impart knowledge but also to make educators recognize the undeniable relevance and significance of digital tools.

Another student teacher highlighted the course's instrumental role in reshaping their grasp of digitalized English teaching. They shared, "This course profoundly impacted my understanding of English teaching in a digital environment. I discovered various online resources and multimedia tools, learning skills from recording lessons to crafting interactive materials and even designing educational games. Platforms like Wordwall and H5P were game-changers, allowing real-time feedback and assessment, truly enhancing my digital teaching strategies." The reflection highlights an essential component of the digital education revolution – the symbiosis between digital tools and teaching pedagogy.

It's not just about understanding digital mechanisms in isolation but utilizing them effectively within specific disciplines. The mention of different e-learning tools as game-changers highlights the importance of tool-specific proficiency, emphasizing that using the right tools effectively can redefine teaching strategies.

The reflections also underscored the course's power to motivate. As a student teacher said, "The introduction to Markdown for lecture creation was a tremendous source of inspiration for me. I had conventionally leaned on Word, which felt somewhat confining. Markdown, on the other hand, presented a versatile avenue, giving my lectures both a visual appeal and multi-functionality." The introduction of Markdown is portrayed as a liberating experience, freeing educators from the confinement of traditional word-processing tools.

A significant pedagogical shift was also evident in the feedback. As one student teacher introspected, "The emphasis on designing courses with games and the principle of 'learning English being the main objective' was eye-opening. It redefined my teaching ethos, spotlighting the demand for English language acquisition as the central goal." The feedback on pedagogical shifts underscores another critical facet: while tools and methodologies evolve, the core objectives of education—like language acquisition—remain indispensable. The course intertwines these core objectives with modern methodologies, ensuring educators don't lose sight of their primary goals.

The course extended beyond mere insights. It brought practical, tangible benefits. A student teacher shared her experience: "The Final Project, after designing the games, was a real-world trial. Actual English learners engaged with my interactive materials, and their feedback was invaluable, pinpointing areas that needed refinement. Such practical exposures are infrequent, and I'm immensely grateful for this golden chance." As this student teacher pointed out, practical exposure prepares future teachers for real-world challenges, making them adaptable and responsive.

Still, the path was interspersed with hurdles. Several student teachers faced challenges, predominantly when integrating AI. One detailed, "The endeavor of crafting lectures using HTML was a blend of challenge and gain. The efficacy in prompting ChatGPT was of the essence. Inconsistencies between expectations and outcomes often necessitated re-prompting or re-examining the code. This iterative troubleshooting, although taxing, enriched my learning, making this course stand out distinctly." Another shared the troubles with Markdown, confessing, "Markdown, especially in Joplin, was so difficult that I had to call for external resources, peer consultations, and even assistance from ChatGPT frequently." Another added, "Balancing HTML and Markdown formatting within Joplin consumed a lot of time. AI-led automation wasn't always accurate." Digital integration, especially with advanced tools and AI, brought forth complexities. The reflections on these hurdles, however, reveal an unexpected benefit. They underline the essence of

perseverance, iterative learning, and the value of troubleshooting in the digital age. These challenges were instrumental in deepening their understanding and refining their skills. Overall, these reflections highlight how the course significantly changed the student teachers. Their journey—filled with new insights, high levels of motivation, practical uses, and challenges—improved their skills with digital tools and refreshed their teaching methods.

Undergraduate student' evaluation

As an integral component of their coursework, student teachers were required to design a comprehensive set of digital teaching resources for use in the undergraduate "Tutorial English" course. This set encompassed a range of materials, including an illustrative video, interactive exercises, an online quiz, and an e-handout.

To guarantee the efficacy of the materials created by the student teachers, an evaluation phase was incorporated, involving feedback from undergraduate students. Having interfaced with all the provided resources, these undergraduate students offered crucial insights into the overall pedagogical quality of the materials. In assessing the quality and adherence to stipulated standards, it emerged that the contributions from 3 out of 11 student teachers did not align with the expected pedagogical benchmarks, and thus, these materials were not incorporated into the undergraduate curriculum.

Numerically, the digital resources designed and created by the student teachers received substantial approval. Averaging scores ranging from 4.35 to 4.71 out of 5, the commendations reflected a high degree of satisfaction and endorsement from the undergraduate evaluators.

Student Teacher 11 reported no progression in her self-evaluation and produced materials that did not meet standards. The instructor observed her low motivation to learn new technology, which likely affected both her self-assessment and work quality. This highlights that motivation and engagement are crucial in pedagogical proficiency, as a

Table 3 Undergraduate students' evaluation on digital materials made by student teachers

Criteria / Students*	Overall satisfaction	Satisfaction with the digital video	Satisfaction with the interactive materials	Gain useful knowledge	Undergraduate Students (persons)
S2	4.58	4.54	4.50	4.57	161
S3	4.50	4.55	4.38	4.57	166
S4	4.58	4.68	4.42	4.62	169
S5	4.42	4.36	4.42	4.39	166
S6	4.40	4.48	4.42	4.44	165
S7	4.71	4.63	4.70	4.64	161
S9	4.58	4.58	4.45	4.59	160
S10	4.54	4.52	4.48	4.59	164

*Note: Undergraduate Students (Satisfaction 1-5)

teacher's willingness to embrace new learning directly influences the quality of their contributions.

Discussion

The evolution of digital tools in pedagogy has dramatically reshaped educational paradigms, requiring educators and learners alike to adapt and grow. In the context of this study, understanding how student teachers' digital competency develops is crucial.

The SAMR model and digital pedagogical evolution

The SAMR model is a framework for integrating technology into teaching and learning. The model presents a structured framework for integrating technology into pedagogical practices. It categorizes the technological integration process into four sequential stages: Substitution, Augmentation, Modification, and Redefinition. Each stage presents a gradational level of technological immersion and sophistication within the instructional environment.

Upon examination of the data gathered in our study, the student teachers' exploration and assimilation of digital tools can be interpretatively mapped onto the SAMR model. Initially, most student teachers began their learning with minimal to no prior knowledge of digital tools. This initial phase predominantly aligned with the Substitution stage, wherein digital technologies served merely as direct replacements for conventional instructional tools. However, as the student teachers' proficiencies developed, a discernible shift was observed. Their interactions with digital tools expanded from mere substitution to the Augmentation phase and, with continued engagement, advanced to the Modification and, eventually, the Redefinition stages, mirroring the advanced stages of the SAMR model. This progression underscores the transformative potential of digital tools when effectively integrated into teaching and learning processes.

However, the transition was punctuated with challenges. Challenges arose when student teachers learned to use advanced tools like ChatGPT for Markdown handout creation. For those unacquainted with AI paradigms and Markdown syntax, this task presented a formidable learning experience. However, viewing these challenges not as setbacks but as valuable learning opportunities is essential. Confronting these hurdles, student teachers had the chance to deeply engage with the SAMR stages in a real-world context. This experience enhanced their understanding of how emerging technologies can be integrated into contemporary teaching methods.

Digital competency for a digitally adept teacher

In today's digital age, the role of a teacher goes beyond traditional teaching methods. This study aligns with Puentedura's (2006) framework, which categorizes teachers' technology

use into a spectrum ranging from 'substitutional' practices to 'redefinition,' where technology not only replaces traditional methods but also creates entirely new possibilities and tasks that were previously inconceivable without its use. Modern education requires a harmonious blend of tried-and-true pedagogical techniques with a sound understanding of digital tools and platforms (Robinson, 2016). As we navigate this evolving landscape, our research highlights three key areas essential for shaping the future digitally adept teacher.

Fostering digital creation and application abilities

To equip future teachers for the digital age, the initial focus should be on enabling them to proficiently create materials using an array of available digital resources, in line with what was suggested (Elstad & Christophersen, 2017). This journey should see them transition from becoming digital tool users to becoming adept digital content creators. The depth of this competency isn't limited to creation alone; it's equally vital to ensure they can strategically apply these digital materials in real-world teaching scenarios. By mastering this dual skill set, teachers will be better positioned to enhance both student engagement and interaction, which are vital components of the modern classroom.

Cultivate resilience through challenges

One of the cornerstones of effective pedagogical training in the digital realm should be preparing educators to confront and navigate challenges confidently. As the technological landscape continually evolves, teachers will inevitably face hurdles, such as integrating emerging AI tools or troubleshooting technical problems. By actively exposing them to these challenges during their training, their problem-solving abilities are refined, and they also internalize the critical role of digitalization in contemporary education. This hands-on experience underscores its importance and solidifies their commitment to utilizing digital tools effectively.

Internalizing the significance of digitalization

The pedagogical paradigm is shifting, and future teachers must grasp the central role of digitalization in this transformation, as mentioned by Lund et al. (2014) and Koc (2013). While it's essential to provide them with the technical skills to utilize digital tools, it's equally critical to instill a deep appreciation for why these tools are paramount. This isn't about replacing traditional methods but understanding that digital tools are essential in many contexts for bridging the gap between teachers and a generation steeped in digital experiences since birth. By recognizing and embracing this shift, future teachers will be better prepared to meet the diverse needs of their students, ensuring a more holistic and impactful learning experience.

Conclusion

Integrating digital tools into modern pedagogy is no longer optional but imperative. By exploring student teachers' digital competency, this study highlighted both the transformative potential of digital tools and the challenges inherent in their adoption. The journey towards digital proficiency is not just about mastering the tools, but understanding their pedagogical significance. As educators grapple with the balance between traditional methods and digital innovations, it becomes evident that training must encompass both the technical aspects and the underlying principles of this integration. Ultimately, the future educator will be digitally competent and pedagogically insightful, ensuring that classrooms are both technologically enriched and pedagogically sound.

This study represents the initial phase of investigating digital materials created by graduate students preparing for careers as English teachers. By employing the SAMR model as a guiding framework for digital material development, the research pulls out encouraging outcomes stemming from carefully designed materials for university-level students. Consequently, future research endeavors should build upon these findings, examining deeper into the effects and further evolution of digital materials within English education, particularly in English as a Foreign Language contexts.

Abbreviations

AI: Artificial Intelligence; CALL Computer-Assisted Language Learning; CEFR: Common European Framework of Reference; DIGCOMP: Digital Competency Framework; EFL: English as a Foreign Language; SAMR: Substitution, Augmentation, Modification, Redefinition; TESOL: Teaching English to Speakers of Other Languages.

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Authors' contributions

The authors are responsible for the research design, data collection, analysis, and interpretation. Both authors have read and approved the final manuscript.

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Availability of data and materials

The data used in this study cannot be shared due to privacy and protection policies. However, processed datasets not included in the manuscript may be available from the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare that there are no competing interests related to this study. All funding sources and affiliations have been disclosed, and there are no financial or personal relationships that could influence the research outcomes.

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References

Basantes-Andrade, A., Casillas-Martín, S., Cabezas-González, M., Naranjo-Toro, M., & Guerra-Reyes, F. (2022). Standards of teacher digital competence in higher education: A systematic literature review. *Sustainability*, *14*(21), 13983. https://doi.org/10.3390/su142113983

Biggs, J., & Collis, K. (1982). *Evaluating the quality of learning: The SOLO taxonomy*. Academic Press.

Cao, J., Bhuvaneswari, G., Arumugam, T., & Aravind, B. R. (2023). The digital edge: Examining the relationship between digital competency and language learning outcomes. *Frontiers in Psychology*, *14*, Article 1187909. https://doi.org/10.3389/fpsyg.2023.1187909

Chapelle, C. A., & Sauro, S. (2017). *The handbook of technology and second language teaching and learning*. Wiley-Blackwell.

Cook, S. A., Ogata, H., Elwell, M. G., & Ikeda, M. (2015). Acculturation in context: Knowledge sharing through ubiquitous technologies. *Research and Practice in Technology Enhanced Learning*, *10*, 19. https://doi.org/10.1186/s41039-015-0017-x

de Bot, K. (2008). Second language development as a dynamic process. *The Modern Language Journal*, *92*(2), 166–178.

Ellis, N. C., & Larsen-Freeman, D. (2009). *Language as a complex adaptive system*. Wiley-Blackwell.

Elstad, E., & Christophersen, K.-A. (2017). Perceptions of digital competency among student teachers: Contributing to the development of student teachers' instructional self-efficacy in technology-rich classrooms. *Education Sciences*, *7*(1), 27. https://doi.org/10.3390/educsci7010027

Esteve, F., Llopis, M. A., & Adell, J. (2020). Digital teaching competence of university teachers: A systematic review of the literature. *IEEE Revista Iberoamericana De Tecnologías Del Aprendizaje*, *15*(4), 399–406. https://doi.org/10.1109/RITA.2020.3033225

Ferrari, A. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe*. EC Joint Research Center: Institute for Prospective Technological Studies. https://data.europa.eu/doi/10.2788/52966

Godwin-Jones, R. (2018). Emerging technologies: Digital literacy in the age of the Internet. *Language Learning & Technology*, *22*(1), 22–25.

Gudmundsdottir, G. B., & Hatlevik, O. E. (2018). Newly qualified teachers' professional digital competence: implications for teacher education. *European Journal of Teacher Education*, *41*(2), 214–231. https://doi.org/10.1080/02619768.2017.1416085

Guillén-Gámez, F. D., Ruiz-Palmero, J., & Gómez-García, M. (2024). Digital competences in research: Creativity and entrepreneurship as essential predictors for teacher training. *Journal of Computers in Education*, *11*, 1263–1282. https://doi.org/10.1007/s40692-023-00299-3

Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. (2016). The substitution augmentation modification redefinition (SAMR) model: A critical review and suggestions for its use. *TechTrends*, *60*(5), 433–441. https://doi.org/10.1007/s11528-016-0091-y

Hampel, R., & Stickler, U. (2012). The use of videoconferencing to support multimodal interaction in an online language classroom. *ReCALL*, *24*(2), 116–137. https://doi.org/10.1017/S095834401200002X

Han, Z.-H. (2019). *Profiling learner language as a dynamic system*. Multilingual Matters.

Healey, D., Hanson-Smith, E., Hubbard, P., Ioannou-Georgiou, S., Kessler, G., & Ware, P. (2019). *TESOL Technology Standards: Description, implementation, integration*. TESOL Publications.

Hiver, P., Al-Hoorie, A. H., & Evans, R. (2022). Complex dynamic systems theory in language learning: A scoping review of 25 years of research. *Studies in Second Language Acquisition*, *44*(4), 913–941. https://doi.org/10.1017/S0272263121000553

Illeris, K. (2002). *The three dimensions of learning*. Roskilde University Press.

Jeng, Y., Wu, T., Huang, Y., Tan, Q., & Yang, S. (2010). The add-on impact of mobile applications in learning strategies: A review study. *Educational Technology & Society*, *13*(3), 3–11.

Kessler, G. (2018). Technology and the future of language teaching. *Foreign Language Annals*, *51*(1), 205–218. https://doi.org/10.1111/flan.12318

Kim, S., Kim, H., & Jang, H. (2013). An analysis of the effectiveness of a program designed to train teachers for ICT-integrated instruction. *Computers & Education*, *69*, 340–350.

Kirschner, P. A., & De Bruyckere, P. (2017). The myths of the digital native and the multitasker. *Teaching and Teacher Education*, *67*, 135–142. https://doi.org/10.1016/j.tate.2017.06.001

Koc, M. (2013). Student teachers' conceptions of technology: A metaphor analysis. *Computers & Education*, *68*(1), 1–8. https://doi.org/10.1016/j.compedu.2013.04.024

Kress, G., & van Leeuwen, T. (2001). *Multimodal discourse: The modes and media of contemporary communication*. Arnold.

Krumsvik, R. J. (2008). Situated learning and teachers' digital competence. *Educational and Information Technologies*, *13*(4), 279–290. https://doi.org/10.1007/s10639-008-9069-5

Krumsvik, R. J. (2014). Teacher educators' digital competence. *Scandinavian Journal of Educational Research*, *58*(3), 269–280. https://doi.org/10.1080/00313831.2012.726273

Lin, R., Chu, J., Yang, L., Lou, L., Yu, H., & Yang, J. (2023). What are the determinants of rural-urban divide in teachers' digital teaching competence? Empirical evidence from a large sample. *Humanities and Social Sciences Communications*, *10*, Article 422. https://doi.org/10.1057/s41599-023-01933-2

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson.

Lund, A., Furberg, A., Bakken, J., & Engelien, K. L. (2014). What does professional digital competence mean in teacher education? *Nordic Journal of Digital Literacy*, *9*(4), 280–298. https://doi.org/10.18261/ISSN1891-943X-2014-04-04

Lund, A., & Erikson, T. (2016). Teacher education as transformation: Some lessons learned from a center for excellence in education. *Acta Didactica Norge*, *10*(2), 53–72. https://www.journals.uio.no/index.php/adno/article/view/2483/2458

Mayer, R. E. (2001). *Multimedia learning*. Cambridge University Press.

Mehrvarz, M., Heidari, E., Farrokhnia, M., & Noroozi, O. (2021). The mediating role of digital informal learning in the relationship between students' digital competence and their academic performance. *Computers & Education*, *167*, 104184. https://doi.org/10.1016/j.compedu.2021.104184

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Puentedura, R. (2006). *Transformation, technology, and education*. http://hippasus.com/resources/tte/

Punie, Y., Brecko, B., & Ferrari, A. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe*. EUR 26035, Publications Office of the European Union. https://doi.org/10.2788/52966

Robinson, K. (2016). The effect of technology integration on high school students' literacy achievement. *Teaching English with Technology*, *16*(3), 3–16.

Rosmawati, R. (2014). Second language developmental dynamics: How dynamic systems theory accounts for issues in second language learning. *The Australian Educational and Developmental Psychologist*, *31*, 66–80. https://doi.org/10.1017/edp.2013.22

Stockwell, G. (2012). *Computer-assisted language learning: Diversity in research and practice*. Cambridge University Press.

Tomlinson, C. A. (2014). *The differentiated classroom: Responding to the needs of all learners*. ASCD.

Tondeur, J., Pareja Roblin, N., van Braak, J., Voogt, J., & Prestridge, S. (2017). Preparing beginning teachers for technology integration in education: ready for take-off? *Technology, Pedagogy and Education*, *26*(2), 157–177. https://doi.org/10.1080/1475939X.2016.1193556

Valtonen, T., Kukkonen, J., Kontkanen, S., Sormunen, K., Dillon, P., & Sointu, E. (2015). The impact of authentic learning experiences with ICT on pre-service teachers' intentions to use ICT for teaching and learning. *Computers & Education*, *81*, 49–58. https://doi.org/10.1016/j.compedu.2014.09.008

Vygotsky, L. S., Cole, M., Jolm-Steiner, V., Scribner, S., & Souberman, E. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

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