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Stamatios Papadakis *Editor*

IoT, AI, and ICT for Educational Applications

Technologies to Enable Education for All

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Stamatios Papadakis

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Preface

The integration of the Internet of Things (IoT), Artificial Intelligence (AI), and Information and Communications Technology (ICT) into educational applications has ushered in a transformative era in learning. IoT devices enable real-time data collection and analysis, enhancing personalized learning experiences for students. AI algorithms can adapt curriculum content to individual student needs, providing tailored support and challenging tasks, ultimately improving learning outcomes. ICT infrastructure empowers educators with tools for interactive teaching, virtual classrooms, and collaborative platforms, breaking down geographical barriers and making education accessible to a global audience. Together, these technologies create a dynamic and engaging educational environment, fostering innovation, improving educational access, and preparing students for a rapidly evolving digital world.

The decision to produce this new book is a response to the growing need for academic literature in emerging research domains already exerting a significant influence on society. These innovative technologies augment the personalization of student learning programs and courses, facilitate tutoring to address students' weaknesses and refine their skills, expedite communication between educators and students, and extend the accessibility of continuous learning opportunities available around the clock.

The target audience for this book comprises preservice educators, practising teachers, academics, researchers, and university faculty members. It also extends to individuals from various disciplinary backgrounds committed to advocating for a comprehensive approach to nurturing and educating young children.

This book comprises eleven chapters contributed by researchers from various corners of the globe, representing nations such as Greece, Turkey, New Zealand, Vietnam, Israel, Russia, Spain, Qatar, and Great Britain. Chapter 1 investigates the self-efficacy levels of preschool teachers in Turkey and Greece regarding integrating Information and Communication Technology (ICT) into their classrooms, focusing on the challenges posed by the COVID-19 pandemic. Grounded in Albert Bandura's Social Cognitive Theory, the research delves into teachers' beliefs and self-efficacy's role in their ICT utilization within an educational context. Employing a cross-cultural adaptation of the Technological Self-Efficacy Scale in Information,

Communication, and Technology (TSES-ICT-PDE), this study juxtaposes the self-efficacy perceptions of Greek and Turkish preschool teachers. The findings reveal no statistically significant disparity in ICT self-efficacy between the two groups. However, despite harboring positive attitudes toward integrating ICT, its implementation in the classroom remained limited, particularly in Turkey, due to practical impediments such as hardware issues, inadequate institutional support, and deficiencies in teacher training programs. These results underscore the imperative of enhancing teachers' ICT self-efficacy and addressing pragmatic challenges to promote effective technology integration in early childhood education, transcending diverse cultural contexts.

Chapter 2 engages in a comprehensive examination of technological advancements in the field of education, which have propelled global initiatives aimed at integrating digital technology into curricula. This integration seeks to equip students with essential twenty-first-century skills, including digital literacy, effective communication, critical thinking, teamwork proficiency, and the capacity to generate original ideas. With approximately seven years remaining to achieve Sustainable Development Goal 4 (SDG4), the focal point of many educational systems centers on this aspiration. SDG4's Objective 4.7 underscores the need to provide learners with opportunities to acquire knowledge and skills conducive to promoting sustainable development. Adopting various technological tools has gained prominence to maximize meaningful student engagement and active participation in the teaching-learning process. This chapter establishes an informative foundation regarding Computer-Assisted Instruction (CAI)'s role in mathematics education while considering its advantages, challenges, and opportunities. The discussion commences by delineating the essence of CAI, its overarching objectives, distinctive features, and delivery modes. Additionally, from a theoretical standpoint, various technology integration frameworks relevant to a CAI environment are explored, contributing to the ongoing discourse on the utilization of CAI in mathematics education. Furthermore, this chapter delves into an extensive review of meta-analysis studies, providing empirical evidence supporting the positive impact of CAI on students' mathematics learning outcomes.

Chapter 3 explores ChatGPT's prospective utility as a tool for creating portfolios within the context of English as a Second Language (ESL) education. E-portfolios have emerged as a valuable instrument for language learners to effectively exhibit their language proficiency, track educational advancements, and showcase personal accomplishments. Nevertheless, constructing an e-portfolio can pose formidable challenges for learners, particularly concerning composing and structuring their reflections and collating their educational artefacts. ChatGPT, a language model underpinned by artificial intelligence, stands poised to ameliorate the portfolio development process by furnishing learners with automated feedback and prompts to aid in shaping their writing and reflective practices. This chapter will extensively examine the existing literature concerning portfolios and language learning, scrutinize the attributes and functionalities inherent in ChatGPT, and proffer insights into pragmatic strategies for the seamless integration of ChatGPT into e-portfolio construction. Additionally, this chapter will accentuate the merits and impediments

associated with using ChatGPT in the domain of e-portfolio development and propose avenues for potential future research endeavors.

Chapter 4 pertains to the influence of globalization on the status of English as a global language, which significantly impacts the teaching and learning of English on a global scale. In the present era, our educational landscape is marked by a rapidly evolving and demanding environment characterized by globalization, technological advancements, and increased mobility. Educators must adapt to this changing landscape by integrating digital resources into daily teaching practices. This groundbreaking research study explored the potential benefits of harnessing Alexa, Amazon's artificial intelligence-based personal assistant, to augment motivation, self-assurance, engagement, and language acquisition outcomes among Israel's English as a Foreign Language (EFL) students. The study's primary objective was to investigate how Alexa could be effectively employed in English language learning to promote favorable student outcomes. Drawing upon theories of language acquisition and pedagogical learning, this research examined how Alexa could be incorporated into the routine teaching process to facilitate the development of English language skills. To achieve this, semi-structured interviews were conducted with a cohort of 60 EFL students who had integrated Alexa into their learning journey. Employing thematic analysis, key themes on the students' interactions with Alexa and the perceived advantages of its use were identified. The research findings illuminated the positive impact of Alexa on students' motivation to engage in English language learning. Furthermore, it was revealed that the use of Alexa enhanced their self-confidence and level of engagement. Alexa's non-judgmental environment proved conducive to language practice. Additionally, students cited vocabulary enrichment, improved pronunciation, enhanced grammar skills, development in listening comprehension, and the availability of immediate feedback as key benefits stemming from the integration of Alexa. These insights enrich our comprehension of the potential offered by AI-driven tools within the domain of language education and underscore the significance of infusing technology into the EFL classroom.

Chapter 5 discusses that in recent years, the scientific community has initiated a rigorous examination of the integration of smart education within the educational domain. The heightened prevalence of technology and artificial intelligence, particularly accentuated during the pandemic, has attracted substantial attention to these educational modalities. Within this context, the authors have undertaken a comprehensive analysis of the core concept of smart education, delving into pedagogical experiences related to the implementation of online education and scrutinizing the potential applications of state-of-the-art technologies. In our research, we aim to shift our focus toward the social risks and challenges that emerge when adopting the smart education paradigm. In a previous scholarly endeavor, we elucidated the fundamental principles underpinning smart education's methodology. Significantly, sociologists have underscored the social risks accompanying integrating smart technologies and artificial intelligence into individuals' daily lives and professional spheres. From our standpoint, it is paramount to understand how smart

education interfaces with and responds to the challenges presented by the emergence of the smart reality.

In contemporary educational contexts, computers have assumed a significant and multifaceted role. They serve as valuable tools for enhancing the educational process. The capacity to animate figures and visual representations, facilitated by appropriate software applications, stimulates students' creativity and bolsters their problem-solving capabilities. As we approach the impending era of the Fourth Industrial Revolution (4IR), computers, leveraged by the advanced Internet of Things, are poised to furnish an extensive wellspring of information for students and educators. Many didactic methods have emerged wherein computers play a central and transformative role. Examples include the APOS/ACE instructional treatment for mathematics instruction, the pedagogical approach of flipped learning, and the utilization of case-based reasoning techniques to tackle complex problems. Computational thinking has emerged as a prerequisite intellectual attribute for proficient problem solvers. Furthermore, applying Artificial Intelligence techniques has facilitated the development of intelligent learning systems. In addition to delving into these progressive developments in the realm of education, Chapter 6 provides an in-depth exploration of the advantages and drawbacks of e-learning when contrasted with conventional learning paradigms. It also focuses on Connectivism, a novel educational theory germane to the digital age. The evolving role of educators in future educational scenarios is scrutinized, and the chapter concludes with a comprehensive discussion regarding the implications of the Fourth Industrial Revolution (4IR), culminating in overarching conclusions.

In light of the global adoption of computer science as an essential component of curricula, the imperative of nurturing a foundation in computational thinking from an early age is widely acknowledged by experts. Concurrently, augmented reality in education is gaining increasing attention within the academic sphere due to its demonstrated positive influence on students' learning outcomes and motivation. ByteEd's "Play Code Learn" series, a collection of STEM (Science, Technology, Engineering, and Mathematics) kits, introduces a novel pedagogical approach that melds unplugged-to-digital methodologies with innovative augmented reality technologies to teach computer science concepts. Chapter 7 presents the findings of a study conducted to evaluate the impact of the inaugural "Play Code Learn" kit, known as "Dinosaur Steps," within the educational landscape of New Zealand. The unplugged instructional approach has proven to be highly advantageous for learners, marking a significant transformation in knowledge retention and comprehension of computer science principles, competencies, and literacy among students who engaged with the kit. Notably, using play-based methodologies has yielded a substantial upsurge in students' motivation for learning. This research underscores the pivotal role of innovative teaching methods in fostering computational thinking and enhancing educational outcomes.

Despite having existed for several decades, Artificial Intelligence (AI) is increasingly pivotal in society. Its pervasive integration across diverse domains, including education, is readily apparent. Notably, effective AI deployment in the classroom has surfaced, demonstrating tangible benefits for both students' learning outcomes

and teachers' professional growth. Nevertheless, AI's growing presence also evokes apprehensions and reservations, particularly concerning its unknown future implications. This research endeavors to elucidate the perspectives held by Spanish educators regarding AI and its application within the educational setting. To this end, a tailored questionnaire was meticulously crafted, validated, and disseminated through various social networks and educational channels. Five hundred ninety-nine educators representing diverse regions and educational levels in Spain responded to the survey. Findings of Chap. 8 reveal that Spanish educators need to gain more and its potential applications within the classroom. They are more inclined to recognize AI's capacity to enhance teacher professional development instead of its potential to improve teaching and learning processes. Additionally, educators acknowledge their need for training to employ AI in education effectively. In conclusion, beyond the imperative for comprehensive training, the successful integration of AI in education necessitates critically examining the ethical dimensions and pedagogical functionalities intrinsic to AI.

Chapter 9 delves into the pertinence of Leadership 4.0 within the domain of Education 4.0 as it pertains to school leaders. This investigation revolves around the knowledge and perceptions held by school leaders concerning Education 4.0, furnishing valuable insights into their comprehension of and readiness for this transformative educational paradigm shift. The empirical research entailed four focus group interviews with 16 school principals from eight countries. These interviews were administered after a webinar focusing on Education 4.0. The findings from this research underscore that while school leaders exhibited limited prior familiarity with Education 4.0, they displayed a degree of recognition of related terminologies and concepts. Notable concerns expressed by these educational leaders encompassed potential disruptions to traditional classroom settings, considerations for the well-being of both teachers and students and the implications for educational equity. Despite these apprehensions, school leaders acknowledged the merits inherent in Education 4.0. They accentuated the significance of equipping themselves and their teaching staff with diverse leadership skills. The concept of agile leadership emerged as particularly critical for effectively navigating the landscape of Education 4.0. This style of leadership centers on adept crisis management, strategic professional development initiatives, and the mobilization of the collective capacity of the educational community. The overarching conclusion drawn from this study emphasizes the imperative for a fundamental paradigm shift in policy structures. This shift is necessary to foster enhanced collaboration and co-construction of educational reform agendas. Furthermore, this underscores the pressing need to augment school leaders' awareness and competency in addressing the challenges of Education 4.0.

Numerous educators, students, and parents are currently immersed in a vast array of digital technologies encompassing both hardware (such as smartphones, tablets, augmented reality (AR) tools, virtual reality (VR) glasses, holographic devices, etc.) and software (including apps, online platforms, and artificial intelligence (AI) chatbots, among others). Many technologies, such as holography and VR glasses, were not initially developed for educational purposes. Nevertheless, there is a discernible trend toward their gradual integration into educational settings. This trend

presents various opportunities and challenges. Educators, learners, and parents widely assume that if digital technologies function effectively in other contexts, they should similarly enhance the teaching and learning process when adapted for educational use. However, the quality and appropriateness of incorporating digital technologies into education require more comprehensive scrutiny. The enthusiasm for this integration surpasses the empirical evidence available in the field. Within this context, Chap. 10 provides insight into how these digital resources may facilitate transformative and innovative mathematics learning experiences, primarily emphasizing AR and AI. Simultaneously, the chapter seeks to delineate the principal challenges inherent to this endeavor. More specifically, the chapter proposes potential applications of AR in mathematics education and examines how AI-based tools can augment the teaching and learning experiences in this subject area. Drawing inspiration from the cultural-historical activity theory (CHAT), this chapter introduces a framework that offers research-grounded principles for developing digital resources conducive to effective learning with emerging technologies. Moreover, it highlights various stakeholders' primary challenges in this evolving landscape.

Amid the global disruptions caused by the COVID-19 pandemic, educational institutions swiftly transitioned from traditional in-person instruction to remote learning modalities as a precautionary measure to curb the spread of the virus. This abrupt and unforeseen shift significantly restructured the educational landscape, compelling the Turkish Higher Education Council (YÖK) to embrace online teaching methodologies. This research study delves into the utilization of Information and Communication Technology (ICT) by preservice preschool teachers at a university as they endeavored to construct a blog to educate preschoolers and their parents about pandemic-related topics. The investigation scrutinized designing and implementing the blog, involving a cohort of 48 preservice teachers enrolled in the Preschool Education Program throughout the academic years 2019–2020 and 2020–2021. Employing a qualitative case study approach, data was collected from various sources, encompassing video recordings of instructional sessions, blogs created by the preservice teachers, and interviews conducted with the participants. The blog's development process encompassed multiple stages, including content selection, digital conversion, blog publication, and content dissemination strategies. While the initial utilization of ICT tools posed specific challenges for the preservice teachers, the study revealed a noteworthy progression in their competence and proficiency over time. In-depth interviews with the participants underscored an improved appreciation of ICT tools and a heightened level of understanding, a direct consequence of their exposure to diverse technological resources throughout the blog development process. Finally, Chapt. 11 highlights the pivotal role of ICT in contemporary teacher education and accentuates its heightened significance, particularly during periods of crisis such as the COVID-19 pandemic.

The book's conclusion encompasses an examination of the latest research and advancements within the field of education, offering insights into forthcoming developments. Furthermore, it succinctly recapitulates pivotal insights and offers supplementary resources for those seeking to delve deeper into the subject. It is

imperative to acknowledge that innovation does not manifest in isolation; rather, it necessitates an atmosphere of receptivity and collaboration between educational systems and their broader contexts. This principle is particularly applicable to the realm of education. The transformational process faced by universities, schools, and educators necessitates comprehensive support, not merely in policy measures but also through engagement with other stakeholders and actors. This book convenes scholars from across the global educational landscape to foster a constructive dialogue to delineate optimal policies and practices for nurturing innovation within the educational sphere. Leveraging internationally comparative data and rigorous analysis, this synthesis of available evidence serves as a foundational resource for integrating these innovative technologies into the educational sector.

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Chapter 1

Examining the Validity and Reliability of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) Among Greek Preschool Teachers: A Comparative Study with Turkey



Stamatios Papadakis , Ali İbrahim Can Gözüm , Ümit Ünsal Kaya ,
Michail Kalogiannakis , and Turgut Karaköse 

Introduction

The COVID-19 pandemic has brought unprecedented educational challenges, including preschool education (Daniel, 2020). As a result, many preschools have had to shift from traditional face-to-face instruction to distance learning approaches in order to ensure the continuity of educational provision (Gözüm et al., 2022a; Yıldırım, 2021). In this context, information and communication technology (ICT) has emerged as a critical factor in enabling preschool teachers to engage with their students remotely effectively.

Self-efficacy, predicated upon a firm conviction in one's abilities, is pivotal for achieving professional success and societal recognition, specifically within teaching and education-related fields. Teachers, as principal agents of societal policy

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execution, are uniquely positioned to directly influence student outcomes, with their competence being a key determinant. Such competence is fundamentally underpinned by self-efficacy, a construct delineated by Bandura (1997) as the belief in one's cognitive, affective, and behavioural capabilities to execute tasks successfully. In education, self-efficacy translates into a teacher's confidence in their capacity to impact students' academic achievements positively. However, a deficiency in self-efficacy may precipitate emotional and behavioural challenges, consequently impairing professional efficacy.

This conceptual framework of self-efficacy is particularly salient in the context of ICT implementation in distance education, where its effectiveness is heavily contingent on the self-efficacy of teachers (Govender & Govender, 2009; Gözümlü et al., 2022a, b; Taş et al., 2021). Specifically, the confidence and competence teachers exhibit in deploying ICT tools and resources dictate the success of such initiatives. Within the sphere of teaching, self-efficacy pertains to an educator's belief in their capacity to successfully undertake specific tasks (Erdem & Demirel, 2007; Pavithra & Kumar, 2012). A substantial body of research underscores the profound influence of teacher self-efficacy on instructional practices, student learning outcomes, and overall educational quality (Burić & Kim, 2020; Küsting et al., 2016; Schwab, 2019).

The Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE), developed by Gözümlü et al. (2022a), was initially intended to gauge the self-efficacy of Turkish preschool teachers in integrating ICT into remote instruction. It is, however, essential to examine the scale's validity and reliability in distinct contexts, such as among Greek preschool teachers, for several reasons. Firstly, cultural and contextual variables can shape how individuals perceive and respond to specific measures. Confirming that the scale accurately represents and measures the intended constructs within the specificities of the Greek cultural and educational milieu is vital. Secondly, this exploration in Greece allows researchers to contribute to a broader understanding of the scale's generalizability and applicability across diverse contexts. This knowledge is invaluable to Greek researchers and international readership, broadening the scale's relevance and informing its future usage across various cultural and educational landscapes. Therefore, the findings of this study hold potential relevance for researchers, educators, and practitioners globally, extending the utility of the TSES-ICT-PDE beyond its initial development and application and thus making the study compelling to a broader audience.

Furthermore, there is a necessity for more comparative investigations, not just between Greece and Turkey but also across different international contexts, of teacher self-efficacy in using ICT for distance education. Such comparative research can illuminate global commonalities and disparities in preschool teachers' perceptions, attitudes, and practices. Recognizing these potential variations allows for creating tailored strategies to bolster teacher self-efficacy and foster effective ICT integration within preschool distance education. While Greece and Turkey serve as initial comparative examples, the implications of this research extend beyond these specific countries. Indeed, the universality of ICT in education means these findings hold considerable relevance for the broader international audience, providing

globally applicable insights and beneficial to educators, researchers, and policy-makers alike.

Hence, the primary objective of this study is twofold. Firstly, it aims to validate and test the reliability of the TSES-ICT-PDE among Greek preschool teachers, ensuring that it is a robust and accurate measure of their self-efficacy in using ICT for distance education. Secondly, it compares teacher self-efficacy in ICT utilization for distance education between Greece and Turkey, shedding light on the similarities and differences in the two countries' educational contexts.

By exploring these research objectives, this study aims to contribute to the existing body of knowledge on the use of ICT in early childhood education, particularly in the context of distance education during the COVID-19 pandemic. By examining the validity and reliability of the TSES-ICT-PDE and conducting a comparative analysis, this research will provide insights that can inform policy and practice, supporting the development of targeted interventions and initiatives to enhance preschool teachers' self-efficacy in using ICT effectively for distance education. Ultimately, this study seeks to advance the field of preschool distance education and promote the continued provision of quality early childhood education in the face of challenging circumstances.

ICT Integration in Early Childhood Education: Benefits, Challenges, and Considerations

Integrating information and communication technology (ICT) in pedagogy has become essential to educational reform globally. ICT is recognized for its critical role in fostering active participation in the information society and supporting children's development in educational settings (Dong et al., 2020; Gayatri, 2020; Kim, 2020; Nikolopoulou & Gialamas, 2015; Peeraer & Van Petegem, 2011).

At the core of these learning environments are teachers, whose beliefs, attitudes, and self-efficacy significantly influence the successful implementation and use of ICT in schools (Bandura, 1993; Badia et al., 2013; Ertmer, 2005; Erdogan, 2011; Harding, 2012; Oye et al., 2014; Tondeur et al., 2012). They are crucial integrators of educational elements and are instrumental in creating conducive teaching and learning environments.

Building on Becker's (2000) exploration into the challenges teachers face when implementing computers in teaching practices, Ertmer (2005) delineated two distinct categories of impediments that could obstruct teachers' effective incorporation of ICT into classrooms. First-order barriers are external constraints such as insufficient resources, inadequate time, lack of training, and limited support. Conversely, second-order barriers emanate from teachers' knowledge base and pedagogical and epistemological beliefs, including the perceived utility of ICT, self-efficacy in its application in pedagogical contexts, and readiness to modify traditional teaching methods.

Subsequently, Tsai and Chai (2013) introduced a third tier of obstacles related to educators' pedagogical thinking and ability to design learning experiences, which must be surmounted to fluidly and actively incorporate ICTs in their classrooms. This suggests that for teachers to architect meaningful learning scenarios and foster efficient learning experiences, they must perceive ICT as an integral component of the educational milieu in their classrooms and a valuable tool to enhance students' learning.

Despite the growing incorporation of ICT into early childhood classrooms, there still needs to be a significant challenge in effectively integrating ICT tools and resources (Aubrey & Dahl, 2014; Leung, 2010). One must not merely focus on the idea of promoting computer literacy or technical skills (Wilson-Strydom & Thompson, 2005) but rather on leveraging these technologies to enhance the teaching-learning process (Aldunate & Nussbaum, 2013; Flanagan & Jacobsen, 2003; Nkula & Krauss, 2014). This challenge persists despite the increasing availability of ICT tools (Balanskat et al., 2006).

External factors like the availability and accessibility of technology, instructional planning time, technical and administrative support, school curriculum, school culture, and pressure for exam preparation all influence the integration of ICT (Abu Al-ruz & Khasawneh, 2011; Tezci, 2011). Moreover, the perceptions and visions of school leaders also play a pivotal role in the implementation process (Pelgrum & Law, 2003). The school's cultural context, too, has a significant mediating role that influences teachers' actions, beliefs, and attitudes towards the use of ICT (Albirini, 2006; Chai et al., 2009).

Simultaneously, internal factors such as teachers' beliefs, understanding of ICT use, attitudes towards technology integration, self-confidence, knowledge, readiness to use ICT, and self-efficacy also come into play (Abu Al-ruz & Khasawneh, 2011; Sang et al., 2011; Palak & Walls, 2009). There are also inherent challenges, such as student mobility, special needs, and anxiety associated with ICT integration (Frederick et al., 2006).

However, despite these concerns and potential limitations (Cordes & Miller, 2000; Gialamas & Nikolopoulou, 2010; Lindahl & Folkesson, 2012; Palaiologou, 2016), proponents argue that the transformative power of ICT lies in its potential to facilitate student-centred teaching and learning approaches (Scrimshaw, 2004). There is consensus that technology can enhance learning and development when used intentionally (NAEYC, 2012).

Indeed, numerous studies have demonstrated the positive impact of ICT on children's curiosity, language and communication skills, creativity, mathematical thinking, problem-solving abilities, cooperation, literacy, and exploratory approaches to leadership (Clements & Sarama, 2003; Hatzigianni & Margetts, 2012; Jack & Higgins, 2019; NAEYC & Fred Rogers Center, 2012; Nikolopoulou & Gialamas, 2015). Also, ICT provides new opportunities to enhance various aspects of early childhood education practices (Kerckaert et al., 2015).

However, the appropriateness of content delivered through ICT applications in classrooms continues to raise concerns (Gözüm, 2022; Gözüm & Kandır, 2021; Papadakis & Kalogiannakis, 2020), thereby emphasizing the need for careful

consideration and responsible use of ICT in early childhood education. Kundu and Bej (2020) proposed the 3E model (encourage, enforce, enhance) for effective integration, accounting for various stakeholders such as teachers, students, and school management to address these complexities. In summation, understanding the potential benefits of ICT integration and addressing the associated challenges can enable policymakers, educators, and researchers to collaboratively harness the full potential of ICT while ensuring its responsible and appropriate use in enhancing early childhood education.

In conclusion, integrating ICT into education represents a multifaceted undertaking fraught with opportunities and challenges. Navigating this dynamic landscape necessitates a deep understanding of its myriad dimensions – the external and internal factors shaping its deployment, the role of teachers as critical integrators, and the potential impact on student learning outcomes. Acknowledging and addressing the concerns about ICT's practical and responsible use in classrooms remains pivotal, especially in early childhood education. It is evident that a strategic and thoughtful approach to ICT integration, as embodied by the 3E model, could pave the way for more effective, enriching, and learner-centred educational experiences. This endeavour warrants concerted effort and collaboration among stakeholders, including educators, policymakers, and researchers. In doing so, we can ensure that the benefits of ICT are optimal while mitigating potential drawbacks, thereby fulfilling the promise of ICT as a transformative tool for education in the twenty-first century.

Enhancing ICT Self-Efficacy Among Preschool Teachers

Bandura's social cognitive theory provides a valuable framework for understanding self-efficacy, an essential concept when exploring teachers' beliefs and confidence in using ICT in their instructional practices. Self-efficacy, as defined by Bandura (1977, 1991, 1993), refers to an individual's belief in their ability to perform specific tasks and produce desired outcomes successfully. According to Barton and Dexter (2020) and Straub (2009), there is an assertion that individuals with elevated levels of self-efficacy are inclined to establish more ambitious objectives, exert more significant effort, and demonstrate increased resilience in the face of challenges and setbacks. In the context of ICT integration, teacher self-efficacy plays a crucial role in determining the extent to which teachers utilize ICT effectively in their classrooms (Ertmer & Ottenbreit-Leftwich, 2010; Morris et al., 2017).

According to Bandura's theory (1997), self-efficacy is influenced by four critical sources of information: mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states. These sources interact to shape individuals' self-beliefs and impact their willingness to engage in new tasks or persevere through challenges. Applying Bandura's theory to the domain of ICT self-efficacy for preschool teachers, we can examine how these sources of information influence their confidence and competence in using ICT tools and resources in their instructional practices.

- **Mastery experiences:** Mastery experiences involve previous personal successes and failures in utilizing ICT in teaching. When preschool teachers have positive experiences with ICT, such as successfully incorporating technology into their lessons or witnessing improved student outcomes, it enhances their self-efficacy. These successes contribute to a sense of accomplishment and the belief that they can effectively use ICT to support teaching and learning.
- **Vicarious experiences:** Vicarious experiences involve observing others, particularly role models, who successfully use ICT in their teaching. When preschool teachers witness their colleagues or other educators effectively integrating ICT into their instructional practices, it can inspire and motivate them to enhance their ICT skills. Observing successful ICT implementation by others gives preschool teachers a sense of possibility and helps them develop confidence in their abilities.
- **Social persuasion:** Social persuasion refers to the feedback, encouragement, and support received from others. In ICT self-efficacy, preschool teachers may receive positive or negative feedback from colleagues, administrators, or professional development providers regarding their ICT skills. Positive feedback and supportive environments that value and promote ICT integration can boost preschool teachers' self-efficacy. Conversely, negative feedback or lack of support can undermine their confidence in using ICT.
- **Physiological and emotional states:** Physiological and emotional states encompass preschool teachers' physical and emotional reactions when using ICT. Factors such as anxiety, stress, or lack of comfort with technology can significantly impact teachers' self-efficacy. When preschool teachers experience anxiety or frustration related to ICT use, it can lower their confidence and hinder their willingness to explore and incorporate technology into their teaching practices. Creating a supportive and empowering environment that addresses these emotional and physiological factors is crucial for enhancing ICT self-efficacy.

By considering these four sources of information within Bandura's social cognitive theory, we can gain insights into the factors that influence preschool teachers' self-efficacy in using ICT. Understanding these factors allows for developing targeted interventions and support systems that foster positive mastery experiences, provide opportunities for vicarious learning, offer constructive social persuasion, and address physiological and emotional states. By promoting self-efficacy in ICT, preschool teachers can become more confident, competent, and motivated in utilizing technology to enhance teaching and learning experiences for young children.

Turkish and Greek Preschool Teachers' Use of ICT

A comparative analysis of teachers' use of information and communication technology (ICT) in education provides valuable insights into the similarities and differences in ICT integration practices across different cultural and educational contexts.

Specifically, examining the use of ICT among Turkish and Greek preschool teachers offers an opportunity to explore the various factors that shape the adoption and implementation of ICT in early childhood education. Turkey and Greece have experienced significant technological advancements and recognized the potential of ICT in supporting teaching and learning processes. However, the extent and nature of ICT integration in preschool settings may vary due to unique cultural, economic, and educational factors influencing teachers' attitudes, beliefs, and access to ICT resources.

While the comparative exploration of Turkish and Greek preschool teachers' use of ICT offers a nuanced understanding of ICT integration in early childhood education within these countries, it also serves as a model for applying the scale in diverse cultural and educational landscapes. This study illuminates localized practices, challenges, and opportunities for incorporating ICT tools in preschool classrooms. It provides invaluable insights into the cross-cultural applicability and broader generalizability of the TSES-ICT-PDE.

Such insights are significant to researchers and practitioners in various countries and cultural contexts interested in employing this scale or similar measures, extending the study's reach beyond the specific Greek and Turkish contexts. Furthermore, understanding the scale's psychometric properties in different contexts aids in advancing measurement science and methodology, yielding benefits for researchers across various disciplines. Thus, while rooted in a specific geographical context, the implications of this study are fundamentally universal, thereby maintaining its relevance to an international readership.

The operational guidelines and regulations of technology use should be present in Greek infant/child centres. Within kindergarten classrooms, information technology (IT) is designated as one of eight learning domains that warrant consideration during the devising and execution of meaningful, purposeful activities for children. As outlined in the Kindergarten Curriculum (2011), the objectives of IT usage encompass (a) the sourcing, organization, management, and generation of multi-form information for idea development, creation, and personal expression; (b) collaboration and fostering communication; (c) promoting exploration, experimentation, problem-solving across subject areas, and invention; and (d) promoting comprehension of how digital technologies are impacting modern society and culture (p. 114). The everyday utilization of information technology encompasses its application in educational contexts as tools for exploration, experimentation, addressing challenges, information management, digital literacy, creative expression across diverse media, and enabling communication and cooperation (Kindergarten Curriculum, 2011, p. 114). IT usage is intertwined with play as the curriculum highlights its role in early childhood education (ECE) for 'strengthening the significance of play as a crucial aspect of their development' (Kindergarten Curriculum, 2011, p. 114). While the curriculum explicitly references incorporating technological tools into play spaces and emphasizes the importance of technology play, a study conducted by Nikolopoulou and Gialamas (2015) in Greece highlighted a requirement for a more comprehensive integration of information technology in early childhood education, despite the curriculum's support for IT utilization.

Additionally, the authors found that early childhood education (ECE) teachers regard technology-based play as a valuable educational approach for young children. They argue that using technology extends beyond casual play and should be integrated into structured learning activities (Nikolopoulou & Gialamas, 2015). Similarly, Manassis (2011) supported this perspective by noting that early childhood educators consider digital games valuable educational resources for infants. Incorporating educational digital games can exemplify effective learning methods, enabling infants to develop practical skills and social behaviours through engaging with these games.

The Early Childhood Education Program formulated in 2013 by the Turkish Ministry of National Education (2013) elucidates the objectives of early childhood education, the consequential developmental outcomes, and the factors influencing these outcomes while providing examples of monthly plans, environmental arrangements, and daily routines. However, upon evaluation of the program, the references to the utilization of IT in early childhood education could be more extensive. The document mentions using computers or technology in early childhood centres in merely three instances. One instance occurs under the segment on developing self-care skills and safeguarding oneself from accidents and harmful situations. In this context, prolonged periods spent watching television or engaging in computer games are portrayed as detrimental. The application of technology in early childhood education continues to be a contentious subject in Turkey. When considering school readiness, academic research primarily focuses on textbooks and review articles, as highlighted by Kartal and Guven (2006). Fewer studies are dedicated to creating surveys to assess teacher perspectives regarding integrating information technology in early childhood centres, as Kol (2012a) demonstrated or delving into their viewpoints (Kol, 2012b). In Kol's research (2012b), among the 33 teachers surveyed, nine reported seldom or no utilization of computer-assisted software (CAS), while the remaining teachers indicated sporadic usage. The obstacles, as perceived by the teachers, were primarily hardware malfunctions, followed by software issues and a lack of technical proficiency among teachers. Early childhood educators opined that CAS is instrumental in developing audiovisual skills and believed that computer usage might engender antisocial behaviours.

As Slutsky et al. (2021) documented, the Kindergarten Curriculum (2011) classifies technology as one of eight pivotal learning spheres in Greece. It underscores its effectiveness in functions, such as gathering and structuring information, promoting communication and cooperation, supporting exploration and issue resolution, and comprehending the role of digital technologies in today's society and culture. However, Nikolopoulou and Gialamas (2015) disclosed an underwhelming technology integration within early childhood education. Their study also endorsed that, according to Greek educators, play is the most potent strategy for young children's learning. In the context of Slutsky et al.'s (2021) research, Greek educators concurred that technology could support children's learning and enhance their preparedness for school. However, a subset of these educators maintained that young children derive more benefits from outdoor play, hence advocating for controlled use of technology.

Research conducted in Greece has examined teachers' perspectives and attitudes towards incorporating ICT in early childhood education. It has been noted that in the field of education, preschool teachers typically hold favourable views regarding the incorporation of computers or information and communication technology (ICT) (Gialamas et al., 2008; Pange, 2008; Tsitouridou & Vryzas, 2003, 2004). However, these favourable sentiments are tempered by concerns regarding the potential adverse effects of ICT on children (Tsitouridou & Vryzas, 2003, 2004).

These attitudes are influenced by many factors, such as tenure, knowledge of and experience with ICT, home computer use, self-confidence in abilities, and in-service training (Tsitouridou & Vryzas, 2003, 2004; Gialamas et al., 2008). Petrogiannis (2010) further identified a significant correlation between teachers' readiness to adopt computer technology and certain psychological factors, including internal control, perceived stress, attitudes towards computers, perceived utility, ease of use, and anxiety.

While there are differences between preservice and in-service teachers (Gialamas & Nikolopoulou, 2010), the former generally display positive attitudes towards ICT use. However, room for improvement remains (Pange, 2008; Toki et al., 2009). These attitudes may be influenced by factors such as years of study, self-efficacy with ICT, and home access to ICT (Nikolopoulou & Gialamas, 2009).

In Greece, early childhood education departments at universities have incorporated ICT modules into the curriculum to enhance preservice teachers' competence in using ICT in education (Nikolopoulou & Gialamas, 2009; Toki & Pange, 2006). For in-service preschool teachers, numerous training programs have been launched at national and European levels (Nikolopoulou & Gialamas, 2009; Tsitouridou & Vryzas, 2004). However, as Gialamas et al. (2008) noted, these efforts need more systematic organization and exhibit a techno-centred orientation. The primary focus, therefore, should be on formulating and implementing effective teacher training programs to help educators develop scientifically grounded perspectives and attitudes towards ICT (Gialamas & Nikolopoulou, 2010).

In a study by Lavidas et al. (2021), the technological pedagogical content knowledge (TPACK) model is identified as a robust theoretical framework for understanding the requisite knowledge for educators to incorporate ICT in teaching effectively. This study evaluated the perceptions of 147 Greek in-service preschool teachers concerning their proficiency and knowledge of integrating ICT into their teaching practices. A scale of 28 items, aligning with the seven domains of the TPACK model, was utilized to assess teachers' perspectives. The validation and reliability of the scale were confirmed. The findings demonstrated that preschool teachers had adequate perceived self-efficacy in integrating ICT across all seven TPACK domains. Factors such as teachers' age, years of teaching experience, and level of education appeared to influence their perceived self-efficacy for integrating ICT.

Historically, TPACK was built on Shulman's (1986) pedagogical content knowledge, encapsulating general pedagogical skills and subject-specific knowledge. Shulman underscored that having content knowledge and basic pedagogical strategies needed to be improved for efficient teaching. TPACK, paralleling PCK, integrates knowledge of technology, subject matter, learner profiles, pedagogical

strategies, and practices essential for competent ICT integration in classrooms (Koehler et al., 2014). Therefore, effective ICT integration in teaching hinges on a profound understanding of the interplay between content, pedagogy, and technology.

Conversely, Turkish educators exhibited apparent hesitance towards the routine incorporation of technology. The Turkish Preschool Education Program (Turkish Ministry of National Education, 2013) delineates the national objectives for early childhood education and mentions technology only in the context of potential harm due to excessive television viewing or computer gaming. This apprehension about technology was mirrored in the responses of Turkish educators participating in Slutsky et al.'s (2021) study. Except for a few, they emphasized that play is a superior methodology for young children's learning and development compared to extensive technology use, expressing fears about its potential to affect children's development detrimentally. They further warned that an overreliance on technology could precipitate attention deficits and antisocial behaviour in children.

As Konca and Tantekin Erden (2021) documented, a cross-sectional survey explored preschool teachers' digital technologies (DT) utilization in early childhood education settings. The study, which involved 167 teachers across 52 different preschools, included questionnaires and the completion of the Attitude Scale for Technological Tools and Materials Use in Preschool Education. It was observed that classrooms were well-equipped with a range of DTs, including television, DVD, computers, and smartphones, with television and computers being the preferred devices for instructional purposes. Despite teachers displaying positive attitudes towards DT application, their usage was notably restrained, primarily encompassing activities such as watching cartoons and listening to music. The research found that the teachers' gender, teaching experience, and attitudes towards ICT did not significantly impact their utilization of DT in the classroom. Their study suggests that despite access to DT and positive attitudes towards its use, teachers' implementation of these tools was limited to certain activities. Thus, to enhance the effectiveness of DT use, it is necessary to identify and address the potential barriers inhibiting successful technology integration in the classroom (Konca & Tantekin Erden, 2021).

An exploration of research in Turkey reveals a generally cheerful disposition from preschool teachers towards technology integration in their classrooms (Konca et al., 2016). Additionally, these educators perceive digital technology (DT) as essential and underscore its beneficial influence (Korkmaz & Ünsal, 2016). Simsar and Kadim (2017) investigated the influence of DT use on teaching approaches among preschool educators, unearthing a pattern of DT application primarily in music and play-oriented activities. Nonetheless, certain impediments were highlighted by some educators, such as hardware-related difficulties with DT and insufficient institutional and technical assistance (Kabadayı, 2006; Simsar & Kadim, 2017). This perspective aligns with the contention that while technology facilitates child learning, its application can be challenging (Lindahl & Folkesson, 2012). Consequently, educators tend to favour the employment of DT primarily in creating educational plans and musical activities in the classroom (Yurt & Cevher-Kalburan, 2011).

In conclusion, the comparative analysis of Turkish and Greek preschool teachers' use of ICT in education reveals an intricate interplay of cultural, technological, and pedagogical dimensions that influence the adoption and integration of ICT. While both countries display significant strides in ICT adoption and acknowledge its potential in early education, they also show a degree of hesitation and measured approach attributed to concerns about potential adverse effects on children. These viewpoints are shaped by numerous factors, including educators' tenure, knowledge and experience with ICT, self-confidence, and training. Addressing these concerns through comprehensive teacher training programs focusing on the technological aspect and pedagogical and content knowledge is imperative. Additionally, strategies to bridge the gap between positive attitudes towards ICT and its actual use in classrooms should be explored. This could be achieved by identifying and mitigating potential barriers to successful technology integration.

The Present Study

This study aims to address two primary research questions that focus on the validity and reliability of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) among Greek preschool teachers, as well as a comparative analysis of teacher self-efficacy in using ICT for preschool distance education between Greece and Turkey. Therefore, the research questions of this study are as follows:

1. What is the validity and reliability of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) among Greek preschool teachers?

This research question focuses on investigating the psychometric properties of the TSES-ICT-PDE scale when applied to Greek preschool teachers. It aims to determine the extent to which the scale accurately measures preschool teachers' self-efficacy in using ICT for distance education. Examining validity and reliability will involve analysing the scale's internal consistency, construct validity, and test-retest reliability among Greek preschool teachers.

2. How does teacher self-efficacy in using ICT for preschool distance education compare between Greece and Turkey?

This research question aims to compare the levels of teacher self-efficacy in using ICT for preschool distance education between Greece and Turkey. By conducting a comparative analysis, this study will explore the similarities and differences in the beliefs, attitudes, and confidence of preschool teachers from the two countries regarding the use of ICT in distance education. The investigation will shed light on potential contextual factors influencing teacher self-efficacy in each country and contribute to a broader understanding of ICT integration in preschool education within these cultural and educational contexts.

By addressing these research questions, this study aims to provide valuable insights into the validity and reliability of the TSES-ICT-PDE scale among Greek preschool teachers and to offer a comparative analysis of teacher self-efficacy in using ICT for preschool distance education between Greece and Turkey. The findings will contribute to the field of early childhood education by informing policy-makers, educators, and researchers about the effectiveness of the scale and the similarities and differences in teacher self-efficacy in the two countries. Ultimately, this research aims to support evidence-based decision-making and the development of targeted interventions to enhance ICT integration in preschool distance education.

Methodology

The principal aim of this study is to conduct a validity and reliability analysis for the scale adaptation of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) in Greece. The study was designed according to the descriptive research method, a quantitative research design. The research primarily focuses on the validity and reliability study of the TSES-ICT-PDE among Greek preschool teachers. At the same time, it also aims to draw an international comparison by contrasting the results with Turkish preschool teachers, among whom the scale was initially developed.

In this context, a descriptive survey method was utilized to ascertain preschool teachers' ICT self-efficacy in Greece and Turkey. Descriptive survey methods are commonly used in educational research as they provide a detailed view of the participants' beliefs, views, and attitudes (Johnson & Christensen, 2004). Thus, this study utilized the descriptive survey method to provide a comprehensive picture of Greek and Turkish preschool teachers' self-efficacy in using ICT for distance education. The cross-cultural comparison aims to shed light on potential differences and similarities and test the scale's robustness and versatility in different cultural and educational contexts.

Participants

The participants of this study consist of 192 Greek and 213 Turkish preschool teachers, selected using the convenient sampling method appropriate to the quantitative research approach. Simple random sampling assures equal probability for each participant to partake in the study. Given that the participants independently joined the study, their prospects of representing the population are high (Büyüköztürk et al., 2011). A total of 405 teachers participated in the research. The gender distribution among the participating teachers is 285 males and 120 females.

Concerning the educational qualifications of the teachers, the distribution is as follows: 220 hold a bachelor's degree, 118 hold a master's degree, and 242 have

Table 1.1 Demographic findings regarding the participants

Country	Teachers' gender		Teachers' educational level			Teaching experience					Total	
	Male	Female	Bachelor's	Master's	PhD	0-5	6-10	11-15	16-20	20±		
Greece	n	131	61	101	56	35	58	12	2	3	3	192
	%	68.2	31.8	52.6	29.2	18.2	30.2	6.3	1.0	1.6	1.6%	100
Turkey	n	154	59	119	62	32	66	19	2	1	1	213
	%	72.3	27.7	55.9	29.1	15.0	31.0	8.9	0.9	0.5	0.5%	100
Total	n	285	120	220	118	67	124	31	4	4	4	405
	%	70.4	29.6	54.3	29.1	16.5	30.6	7.7	1.0	1.0	1.0%	100

doctoral degrees. The teaching experience of the teachers is distributed across various ranges: 124 teachers have 0–5 years of experience, 31 teachers have 6–10 years, four teachers have 11–15 years, four teachers have 16–20 years, and four teachers have more than 20 years of teaching experience.

The demographic information on the distribution of participants across countries is provided in Table 1.1.

Data Collection Instruments

This research employed two data collection instruments: a personal information form and the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE).

Personal information form: This form was prepared by the researchers to gather demographic data from the teachers, including gender, educational level, and teaching experience. A consent section was included at the top of the form, explicitly explaining that the data would only be collected from teachers who volunteered to participate in the study.

Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE): The TSES-ICT-PDE was developed by Gözümlü et al. (2022a) with the participation of 555 preschool teachers in Turkey. The scale underwent an exploratory factor analysis, followed by a confirmatory factor analysis. The exploratory factor analysis identified three factors: information, communication, and technology. The ‘information’ factor comprises six items, ‘communication’ consists of 6 items, and ‘technology’ includes five items. The scale’s Cronbach alpha (α) values were above the acceptable threshold of 0.70: for the overall scale ($\alpha = 0.904$), for the information factor ($\alpha = 0.928$), for the communication factor ($\alpha = 0.884$), and for the technology factor ($\alpha = 0.845$). The confirmatory factor analysis (CFA) of the three-factor structure demonstrated excellent model fit indices: chi-square ($\chi^2 = 249.527$; $df = 116$; $p < 0.001$), and the chi-square/degrees of freedom ratio ($\chi^2/df = 2.15$), which is below 3 indicat-

ing a good fit, adjusted goodness of fit index (AGFI = 0.92), comparative fit index (CFI = 0.94), goodness of fit index (GFI = 0.95), incremental fit index (IFI = 0.95), normed fit index (NFI = 0.90), and root mean square error of approximation (RMSEA = 0.04).

Data Collection Process

The researchers utilized Google Forms to prepare the data collection instruments in Greek and Turkish. These electronic forms were then disseminated to potential participants through social media applications like Facebook and WhatsApp. It is important to note that the institutions where participants were employed did not assume any responsibility for distributing these electronic forms.

The forms included a consent section where participants affirmed their voluntary participation in the study. Additionally, an ethical statement ensured that participants' data would not be shared with third parties. The researchers provided their email addresses and contact information within the digital forms, allowing participants to acquire further information about the research and ask any questions.

After consenting to participate in the study, participants shared their personal information and completed the items of the data collection tool. An open-ended question was included in the digital form, providing an opportunity for those teachers who wanted to avoid completing the scale items or to express their opinions on the comprehensibility of the scale items. Notably, no participants expressed any negative views on mandatory items or concerns regarding their comprehensibility.

Data Analysis

The data analysis in this research was carried out in two stages. The first stage comprised validity and reliability analyses directed towards the data collected from Greek participants. The second stage involved analyses to compare data collected from Greek and Turkish participants.

In the first stage, confirmatory factor analysis and item-total correlation, item discrimination, and internal consistency analyses on item statistics were performed. The second stage involved the implementation of an independent t-test for comparing Greek and Turkish teachers.

Descriptive statistics, such as mean, standard deviation, frequency, and percentage, were utilized to describe the participants' demographic data and provide a descriptive account of the data gathered through the measurement tool.

Assumptions

When the data was analysed, the assumptions of confirmatory factor analysis (CFA) and independent t-tests were examined. The dataset from Greek participants was solely used to investigate the assumptions of CFA, whereas the dataset from Greek and Turkish participants was amalgamated for the independent t-test.

Before conducting the CFA, multivariate normality values in the Greek participants’ dataset were scrutinized. The CR values in the dataset from Greek participants were under 10, and both kurtosis (0.618) and skewness (0.745) values in the datasets ranged between -3 and + 3. Therefore, the Greek participants’ dataset was determined to exhibit a normal distribution.

After examining the multivariate normality values, model fit values were reviewed before the CFA analysis, and levels of fit were determined according to the literature (see Table 1.2) (Gürbüz & Şahin, 2018).

When comparing the data of Greek and Turkish teachers, the assumptions of the independent t-test were examined. The Kolmogorov-Smirnov test was performed on the data for Greek ($n = 192$) and Turkish ($n = 213$) teachers. As there was no significant difference ($p > 0.05$), it was assumed that both groups showed a normal distribution.

Procedure

The adaptation process of the TSES-ICT-PDE scale for Greek teachers was carried out by the researchers in the following stages:

- Determining the psychometric property to be researched and scale selection: In line with the aim of this study, it was decided that the TSES-ICT-PDE scale could be adapted for Greek teachers as it is suitable and current in terms of its psychometric properties (Seçer, 2015, p. 68).

Table 1.2 Model fit indices for the validation of the TSES-ICT-PDE scale

Measure	Acceptable fit ^a	Good fit ^a	Model fit values
(χ^2/sd)	$3 < \chi^2/sd \leq 5$	$\chi^2/sd \leq 3$	1.448
RMSEA	$0.05 < RMSEA \leq 0.06$	$RMSEA \leq 0.05$	0.048
NFI	$0.90 \leq NFI < 0.95$	$0.95 \leq NFI < 1$	0.924
CFI	$0.90 \leq CFI < 0.95$	$0.95 \leq CFI < 1$	0.975
GFI	$0.90 \leq GFI < 0.95$	$0.95 \leq GFI < 1$	0.914
AGFI	$0.90 \leq AGFI < 0.95$	$0.95 \leq AGFI < 1$	0.904
IFI	$0.90 \leq IFI < 0.95$	$0.95 \leq IFI < 1$	0.975

^aAnderson and Gerbing (1984), Hooper et al. (2008), Hu and Bentler (1999), Marsh and Hau (1996), Schermelleh-Engel et al. (2003), Tabachnick and Fidell (2013)

- Translation into Greek: The translation was performed by experts proficient in the language the scale was written in Turkish and the adapted language was Greek. Seçer (2015, pp. 68–69) recommends that the translations be done by at least two Greek and six foreign language experts. The researchers from both countries ensured the proper translation of each item by discussing each one. After the translations were done, they were reviewed by six language experts from Greece. The translators chosen for this phase were experts in the literature and specialized in the translated language (Çapık et al., 2018, p. 203). The Greek translators' language levels and linguistic knowledge are native-level proficiency (Hambleton & Patsula, 1999, p. 5).
- Comparison of Greek and Turkish measurement tools in a common language: After the TSES-ICT-PDE scale was translated into Greek, an English version was prepared by experts who speak Greek and English. The Turkish version was prepared by experts who speak both Turkish and English. The translations made by different experts were compared in terms of language and meaning. The translation's semantic relation was checked through English, a common language (Hambleton & Patsula, 1999, p. 6). All 17 items were found to retain their original meaning.
- Back translation method from common language: The scale items translated into English were sent back to experts proficient in both languages for translation back into their original languages. After completing the back translation process with the help of two Greek and Turkish language experts, the original and final Turkish texts were compared. It was observed that the Greek and Turkish versions of the items were consistent with the initial translation (Seçer, 2015, p. 71).
- Preparation of Greek scale form and pilot application: The Greek version of the scale was designed similarly to the original one. Greek researchers conducted face-to-face interviews with six teachers, applying the scale one-to-one to examine the comprehensibility of the Greek scale form. Open-ended questions were used to examine language comprehensibility. The 17-item scale form contained the meaning derived from Turkish researchers (Hambleton & Patsula, 1999, p. 6).
- Main application of the Greek scale form: The Greek version of the measuring instrument was applied to 193 teachers. Since the number of items in the measuring tool is 17, the main application was made with more than 170 teachers, which is ten times the number of items.
- Validity and reliability processes to be applied to the scale: Descriptive factor analysis was not conducted on the data collected with the Greek scale form. The structure of the scale was theoretically identified in the Turkish version. Therefore, a confirmatory factor analysis was conducted on the data of Greek participants to determine the validity of the three-factor theoretical structure (Şeker & Gençdoğan, 2014, p. 35).

Findings

The findings of the research questions are sequentially presented. Specifically, the question, ‘What is the validity and reliability of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) among Greek preschool teachers?’ is the focal point of our initial discussion. In order to comprehensively address this query, the findings related to the first research question have been organized into two subsections: First, we explore the results derived from the confirmatory factor analysis, which assesses the construct validity of the TSES-ICT-PDE among Greek preschool teachers. Subsequently, we delve into the reliability analysis findings, examining the consistency and stability of the TSES-ICT-PDE scores. Each section provides critical insights into the utility and reliability of the TSES-ICT-PDE as a measure of Greek preschool teachers’ self-efficacy in using ICT for distance education.

Confirmatory Factor Analysis (CFA) Findings

Several fit indices were considered and assessed as acceptance criteria in the existing literature to evaluate the appropriateness of the factor structure for the CFA study group. These indices include the chi-square to a degree of freedom ratio (χ^2/df), root mean square error of approximation (RMSEA), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI), and incremental fit index (IFI). The fit index values are presented in Table 1.2.

Based on the findings presented in Table 1.2, the CFA fit index values for the three-factor structure of the scale are as follows: $\chi^2 = 163.441$, $sd = 113$, $p = 0.000$, $\chi^2/sd = 1.448$ (below 3 indicating a good fit according to Jöreskog & Sörbom, 1993). The RMSEA value is 0.048, indicating a good fit based on Hu and Bentler (1999). The NFI value is 0.924, indicating an acceptable fit, and the CFI value is 0.975, indicating a good fit, according to Tabachnick and Fidell (2001). The GFI value is 0.914, suggesting an acceptable fit, while the AGFI value is 0.904, indicating an acceptable fit based on Hooper et al. (2008). Furthermore, the IFI value is 0.975, suggesting a good fit based on Marsh and Hau (1996). Overall, the scale demonstrates good fit values when examined. Figure 1.1 provides standardized estimates resulting from the CFA analysis.

Upon examining the findings from the first-level factor analysis, as illustrated in Fig. 1.1, a positive correlation was identified between the measurement tool’s information factor and communication at 0.58, technology and communication at 0.51, and information and technology at 0.43. This implies a significant interplay among the factors – information, communication, and technology – signifying their integral roles in shaping the teacher self-efficacy in the use of ICT at home for preschool distance education.

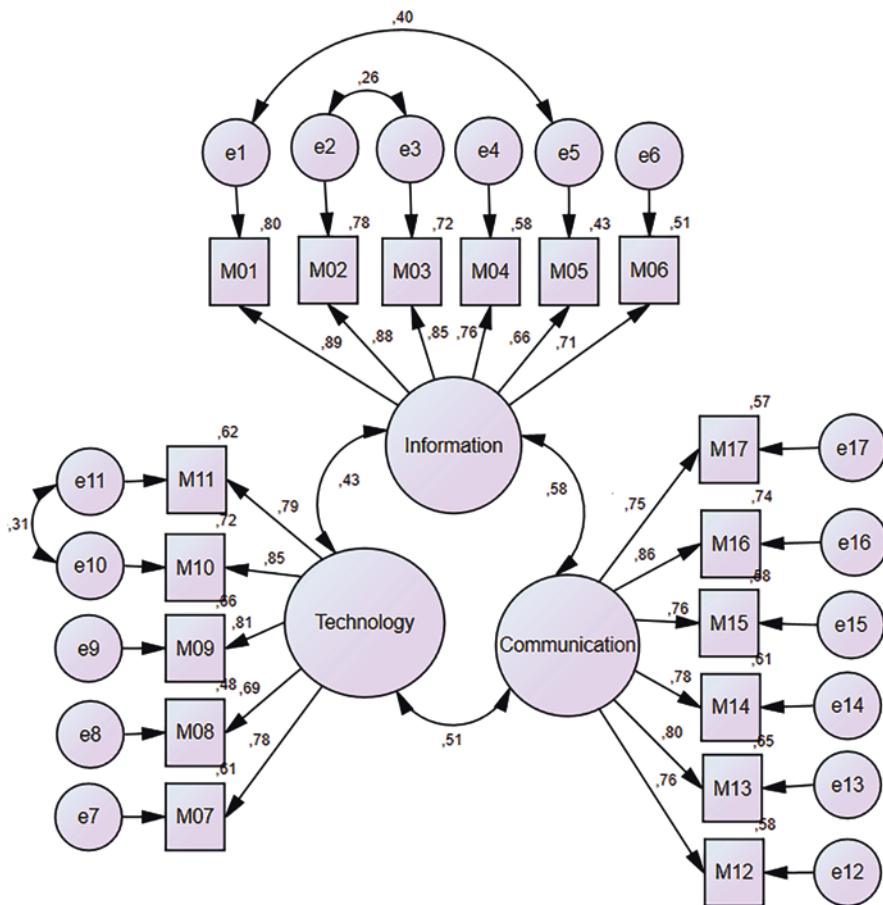


Fig. 1.1 First-level DFA model

Table 1.3 shows the first- and second-level confirmatory factor analysis (CFA) results. The items were found to be meaningfully placed under their respective factors and the factors under the TSES-ICT-PDE, as significant at a ($p < 0.001$) level. Adjustments, or modifications, were made between M1 and M5 and M2 and M3 under the information factor. In contrast, under the technology factor, modifications were made between M10 and M11. The most strongly related item within the information factor was M1, while M10 had the highest estimated value among the items under the technology factor.

Furthermore, the highest estimate value under the communication factor was taken by M16. All the items within the measurement tool were significantly ($p < 0.001$) placed under the scale factors. Therefore, the structural validity of the measurement tool has been verified within the Greek participants' dataset according to the CFA. This demonstrates the robustness of the Teacher Self-Efficacy Scale in

Table 1.3 Standard error and CR values of standardized and unstandardized factor loadings for TSES-ICT-PDE scale from CFA

CFA				Std estimate	Unstd estimate	SE.	CR.
Second level	ICT	->	Technology	0.564	1.000		
	ICT	->	Communications	0.761	1.405	0.237	6.358***
	ICT	->	Information	0.615	2.125	0.358	6.246***
First level	Information	->	M001	0.894	1.000		
	Information	->	M002	0.883	0.983	0.061	16.121***
	Information	->	M003	0.848	0.928	0.062	14.907***
	Information	->	M004	0.759	0.846	0.066	12.919***
	Information	->	M005	0.656	0.742	0.060	12.269***
	Information	->	M006	0.713	0.774	0.066	11.706***
	Technology	->	M007	0.782	1.000		
	Technology	->	M008	0.693	0.856	0.086	9.959***
	Technology	->	M009	0.814	0.994	0.082	12.084***
	Technology	->	M010	0.850	1.087	0.090	12.102***
	Technology	->	M011	0.785	0.952	0.087	10.948***
	Communication	->	M012	0.761	0.995	0.093	10.664***
	Communication	->	M013	0.803	1.066	0.094	11.321***
	Communication	->	M014	0.783	1.017	0.092	11.005***
	Communication	->	M015	0.762	0.972	0.091	10.674***
	Communication	->	M016	0.858	1.147	0.094	12.176***
	Communication	->	M017	0.754	1.000		

*** $p < 0.001$

the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) in assessing the relevant constructs within the Greek context.

Findings of Reliability

Delving into the reliability findings in Table 1.4, the Cronbach’s alpha (α) values for the measurement tool and its respective factors provide compelling evidence of commendable internal consistency. With an alpha value of 0.837 for the measurement tool overall and the information factor, communication factor, and technology factor recording alpha values of 0.914, 0.907, and 0.885, respectively, these figures substantially exceed the generally accepted threshold of 0.70. This leads to the inference that the measurement tool and its factors uphold reliability in the context of internal consistency (Murphy & Davidshofer, 1994).

An examination of the item-total correlation (r) between the items in the scale and their respective factors was also undertaken. These correlation coefficients range from 0.30 to 0.70, indicative of moderate to strong correlations (Büyüköztürk, 2011). Specifically, the information factor presented a correlation range of 0.663 to

Table 1.4 Item-wise analysis and Cronbach’s alpha values for the TSES-ICT-PDE scale

Factor	No	Item statistics						Cronbach’s alpha
	r	\bar{x}	sd	Lower 27% group ($\bar{x}1$)	Upper 27% group ($\bar{x}2$)	t	(α)	
Information	M1	0.845	3.15	0.799	2.65	3.65	7.173***	0.914
	M2	0.828	3.20	0.794	2.77	3.65	6.143***	
	M3	0.800	3.26	0.781	2.85	3.58	5.053***	
	M4	0.829	3.20	0.796	2.92	3.63	4.822***	
	M5	0.785	3.26	0.807	2.88	3.67	5.297***	
	M6	0.663	3.22	0.775	2.88	3.62	5.140***	
Technology	M7	0.745	3.27	0.975	2.54	4.08	11.136***	0.885
	M8	0.661	3.24	0.941	2.63	3.98	8.873***	
	M9	0.762	3.21	0.931	2.63	3.96	8.974***	
	M10	0.755	3.14	0.974	2.42	4.08	12.505***	
	M11	0.692	3.20	0.924	2.50	3.88	9.676***	
Communication	M12	0.711	3.54	0.861	2.81	4.02	9.095***	0.907
	M13	0.760	3.52	0.874	2.85	4.06	9.449***	
	M14	0.740	3.52	0.856	2.96	4.06	7.924***	
	M15	0.715	3.58	0.840	2.88	4.04	8.646***	
	M16	0.811	3.52	0.880	2.81	3.98	8.625***	
	M17	0.715	3.49	0.874	2.87	3.92	7.168***	
Total							0.837	

*** $p < 0.001$

0.845, the technology factor ranged from 0.661 to 0.755, and the communication factor showcased a range from 0.711 to 0.811. It is important to note that an r value below 0.30 ($r < 0.30$) signals a low correlation between the item and the factor, typically prompting the recommendation to eliminate the item from the scale. However, all items within our measurement tool exceeded this threshold. Items M6, M8, and M11 displayed moderate correlation, while all other items manifested strong correlations. This reinforces the reliability and robustness of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) as an instrument for gauging pertinent constructs in the context of Greek preschool teachers.

As illustrated in Table 1.4, the distinguishing capability of the test items within the scale stems from their psychometric properties. Specifically, they can differentiate between teachers with high and low ICT self-efficacy beliefs (Kalaycı, 2008). To examine this further, teachers’ ICT self-efficacy scores were stratified into two groups: a lower group comprising 27% of the sample and an upper group comprising 27%. After applying an independent t-test to these groups, it was discerned that all items on the scale manifest a significant difference at the $p < 0.001$ level. Consequently, the inference can be drawn that the items in the measurement tool are aptly designed to distinguish between teachers with high ICT self-efficacy and

Table 1.5 Comparison of the findings regarding TSES-ICT-PDE and its sub-factors between Greece and Turkey

Variable	Country	N	Mean	SD	df	t	p
Information	Greece	192	19.27	3.97	403	0.355	0.723
	Turkey	213	19.40	3.53			
Technology	Greece	192	16.05	3.92	403	1.381	0.168
	Turkey	213	16.63	4.42			
Communication	Greece	192	21.15	4.28	403	1.348	0.179
	Turkey	213	20.68	2.71			
TSES-ICT-PDE	Greece	192	56.48	7.74	403	0.597	0.551
	Turkey	213	56.92	6.75			

those with low ICT self-efficacy. This finding substantiates the discriminant validity of the scale, asserting its suitability as a tool for evaluating variations in ICT self-efficacy among teachers.

Transitioning from examining the scale’s psychometric properties, we now address our central research question: ‘How does teacher self-efficacy in using ICT for preschool distance education compare between Greece and Turkey?’ Findings pertinent to this inquiry are encapsulated in Table 1.5, which presents an intriguing comparative perspective on the self-efficacy of preschool teachers in Greece and Turkey in using ICT for distance education. This cross-national comparison sheds light on the potential differences and similarities in teachers’ self-efficacy across the two countries, providing valuable insights for policy implications and future research directions.

According to Table 1.5, upon a comparison of the scores on the TSES-ICT-PDE and its sub-factors between Greece and Turkey, it was observed that there was no significant difference in the information factor scores between preschool teachers in Greece and Turkey ($t(403) = 0.355; p = 0.723; p > 0.05$). When looking at the technology factor, there was also no significant difference discerned between Greek and Turkish preschool teachers ($t(403) = 1.381; p = 0.168; p > 0.05$). Moreover, the analysis of the communication scores revealed no significant discrepancy between Greek and Turkish preschool teachers ($t(403) = 1.348; p = 0.179; p > 0.05$). Lastly, there was no significant variance found between Greek and Turkish preschool teachers’ ICT self-efficacy scores ($t(403) = 0.597; p = 0.551; p > 0.05$).

Conclusions and Discussion

The primary aim of this study, which was the adaptation of the Teacher Self-Efficacy Scale in the Use of ICT at Home for Preschool Distance Education (TSES-ICT-PDE) for preschool teachers in Greece, has resulted in a reliable and valid form of the scale. In this context, the findings obtained from the validity and reliability analyses performed in this study are intended to be discussed in comparison to the

results of the research conducted by Gözümlü et al. (2022a), not only regarding the structural validity of the scale but also the ICT self-efficacy of Greek and Turkish preschool teachers.

In the first-level confirmatory factor analysis conducted on the ICT scale of the Greek participants, relationships of 0.43 between knowledge and technology, 0.51 between technology and communication, and 0.58 between knowledge and communication were identified. In the validity and reliability study conducted in Turkey, where the original measurement tool was developed, there were 0.49 between knowledge and technology, 0.59 between technology and communication, and 0.63 between knowledge and communication (Gözümlü et al., 2022a). An interesting result in this context is that when the magnitudes of the relationships between the ICT self-efficacy of Greek and Turkish preschool teachers are arranged from large to small, the relationship between knowledge and communication is the largest, and the relationship between knowledge and technology is the smallest. This result, in light of the similarity of relationships among ICT self-efficacy sub-factors for Greek and Turkish preschool teachers, suggests that in-service training applied to teachers in both countries originates from everyday needs.

The results of the second-level confirmatory factor analysis conducted on the ICT scale of the Greek participants revealed standardized estimate values of 0.564 for technology, 0.615 for knowledge, and 0.761 for communication among the sub-dimensions of the ICT scale. In Turkey, where the original form of the scale was developed, the standardized estimate values were 0.67 for technology, 0.73 for knowledge, and 0.87 for communication (Gözümlü et al., 2022a, b). In this context, the magnitudes of the relationships between the scale and the sub-factors are similar according to the research results conducted in Greece and Turkey. This outcome also indicates that the tendencies of Greek and Turkish preschool teachers towards the measured psychometric property are similar.

Examining the literature and the findings from the comparative analysis of Turkish and Greek preschool teachers' use of ICT in education provides a nuanced understanding of the complexities and challenges underpinning ICT integration in early childhood education.

Bandura's social cognitive theory was employed as a conceptual framework to investigate teachers' beliefs and self-efficacy in using ICT. In Bandura's social cognitive theory, self-efficacy is the belief in one's capability to perform a specific task. For preschool teachers during COVID-19, having high self-efficacy in ICT use at home is more meaningful and challenging than their level of professional development in the classroom. Indeed, the solutions teachers individually devise at home for the challenges they encounter concerning ICT will facilitate proposing solutions when they confront similar problems in the classroom (Gözümlü et al., 2022a). Consistent with earlier studies (Moos & Azevedo, 2009; Morris et al., 2017; Weigold & Weigold, 2021), this research confirmed that self-efficacy significantly influences how ICT is employed in classrooms.

Even acknowledging ICT's importance in education, Turkish and Greek teachers have disagreed with extensive technology use. This apprehension seems rooted in concerns about the potential adverse effects of technology on children's

development, attention span, and social behaviour (Slutsky et al., 2021). These concerns align with prior research (Tsitouridou & Vryzas, 2003, 2004) that underscores the delicate balance educators often strive to maintain between leveraging the benefits of ICT and mitigating its potential risks. Therefore, the self-efficacy of preschool teachers in ICT needs to be supported. Nevertheless, a critical aspect of supporting teachers' ICT self-efficacy is determining their levels of self-efficacy. For these reasons, the scale adapted in this research is critically important in determining the ICT self-efficacy of Greek and Turkish teachers.

When comparing the results of the Greek validity and reliability test for the measurement tool (TSES-ICT-PDE) with the Turkish participants' results, no significant difference was found in the TSES-ICT-PDE among the knowledge, communication, and technology factors. A literature review shows that no significant difference was found when comparing the STEM pedagogical content knowledge of Turkish and Greek preschool teachers, as conducted by Gözümlü et al. (2022b). It was determined in both countries that in-service training in STEM has a positive contribution to the development of STEM pedagogical content knowledge. In this context, one of the critical results of this research, the lack of significant differences in the TSES-ICT-PDE scores of Greek and Turkish preschool teachers, is similar to the research results of Gözümlü et al. (2022b). Moreover, the research by Papadakis et al. (2022) found no significant difference in the strategies towards parental mediation of the digital games their children play.

Because there is consistency in the research results with Greek and Turkish participants, the lack of significant difference between Greek and Turkish teachers' TSES-ICT-PDE scores can be accepted as an indicator that criterion validity has been achieved. However, this result is crucial for scale development study and for the ICT self-efficacy of early childhood educators and, consequently, for classroom technology integration.

Research on classroom technology integration is being conducted in Greece and Turkey. While the self-efficacy of Greek preschool teachers in integrating ICT across all seven domains of the technological pedagogical content knowledge (TPACK) model is being explored (Lavidas et al., 2021), in Turkey, Gözümlü and Demir (2021) have examined the TPACK confidence of preschool teacher candidates towards science teaching. The research found that supporting the teacher candidates' technology knowledge resulted in developing both technical content knowledge and technological pedagogical content knowledge. Therefore, the lack of significant differences in the technology dimension of Greek and Turkish preschool teachers should be considered a significant result that needs to be supported in both countries. Researchers are aware of the importance of supporting teachers' ICT self-efficacy in integrating ICT into classrooms but are also aware of the physical factors in classroom technology integration. In this context, a literature review reveals that, interestingly, despite the generally positive attitudes towards incorporating ICT in teaching, its actual use in classrooms appeared limited, particularly in Turkey (Konca & Tantekin Erden, 2021). This divergence may be attributed to various practical barriers such as hardware malfunctions, insufficient institutional and

technical support (Kabadayi, 2006; Simsar & Kadim, 2017), and a lack of systematic organization in teacher training programs (Gialamas et al., 2008).

Such barriers emphasize the crucial role of teacher training programs in fostering ICT integration in early childhood education. While some initiatives have been undertaken in Greece to enhance preservice and in-service teachers' ICT competence (Nikolopoulou & Gialamas, 2009; Tsitouridou & Vryzas, 2004; Toki & Pange, 2006), these programs have often been criticized for their techno-centred orientation, underscoring the need for a more holistic approach. Such an approach should consider the pedagogical implications of ICT and develop teachers' understanding of how to incorporate technology effectively into their instructional practices.

In conclusion, this study's findings highlight the multifaceted dynamics that influence the adoption and integration of ICT in Turkish and Greek preschool education. The key to enhancing ICT use in early childhood education is a comprehensive teacher training approach that prioritizes pedagogical over technological knowledge and strategies to address the practical barriers to technology use in classrooms. Further research could investigate these dimensions in more depth, thereby contributing to developing more effective policies and strategies for ICT integration in early childhood education.

Limitations and Suggestions

While the present study has elucidated noteworthy findings, certain limitations need to be recognized, which, in turn, pave the way for future research endeavours. The absence of statistically significant differences between Greek and Turkish preschool teachers' ICT self-efficacy presents a promising avenue for future research. Though the lack of difference might indicate parity in skills, it does not inherently confirm that the current self-efficacy levels are optimal. As such, future investigations should identify areas where educators in both nations might need more support or feel more confident, shaping these insights into targeted professional development and support initiatives.

The underlying causes of similar self-efficacy levels between Greek and Turkish educators is another aspect that warrants future exploration. The possible role of shared cultural, professional, or pedagogical experiences, or the impact of education policies and strategies, could be investigated to understand these parallels.

On a practical note, the findings of this study suggest the necessity for continuous interventions to foster ICT self-efficacy among preschool teachers. This entails not only infrastructural enhancements but also designing professional development opportunities that cater to preschool educators' specific, nuanced needs in ICT-enabled education.

Moreover, this research could be extended to include other countries or varied educational stages, thereby broadening the validation of TSES-ICT-PDE and facilitating a comprehensive, global comparison. Such endeavours can enhance our

understanding of how different cultural, pedagogical, and systemic factors influence teacher self-efficacy in using ICT for distance education and consequently inform universally appropriate, efficacious strategies and practices. In summary, this study is an essential contribution to the domain of preschool teachers' ICT self-efficacy, particularly in Greece and Turkey, while concurrently inciting an array of future research possibilities in this critical field.

References

- Abu Al-ruz, J., & Khasawneh, S. (2011). Jordanian preservice teachers' and technology integration: A human resource development approach. *Educational Technology and Society, 14*, 77–87.
- Albirini, A. (2006). Teachers' attitudes toward information and communication technologies: The case of Syrian EFL teachers. *Computers and Education, 47*(4), 373–398.
- Aldunate, R., & Nussbaum, M. (2013). Teacher adoption of technology. *Computers in Human Behavior, 293*, 519–524.
- Aubrey, C., & Dahl, S. (2014). The confidence and competence in information and communication technologies of practitioners, parents and young children in the early years foundation stage. *Early Years, 34*(1), 94–108.
- Badia, A., Meneses, J., & Sigales, C. (2013). Teacher's perceptions of factors affecting the educational use of ICT in technology-rich classrooms. *Electronic Journal of Research in Educational Psychology, 11*(3), 786–808.
- Balanskat, A., Blamire, R., & Kefala, S. (2006). *A review of studies of ICT impact on schools in Europe*. European Schoolnet.
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191.
- Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*(2), 248–287.
- Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28*(2), 117–148.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. Freeman.
- Barton, E. A., & Dexter, S. (2020). Sources of teachers' self-efficacy for technology integration from formal, informal, and independent professional learning. *Educational Technology Research and Development, 68*(1), 89–108.
- Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: Is Larry Cuban right? *Education Policy Analysis Archives, 8*(51), 51. <https://doi.org/10.14507/epaa.v8n51.2000>
- Burić, I., & Kim, L. E. (2020). Teacher self-efficacy, instructional quality, and student motivational beliefs: An analysis using multilevel structural equation modeling. *Learning and Instruction, 66*, 101302. <https://doi.org/10.1016/J.LEARNINSTRUC.2019.101302>
- Büyükoztürk, Ş. (2011). *Sosyal Bilimler İçin Veri Analizi El Kitabı – İstatistik, Araştırma Deseni, Spss Uygulamaları ve Yorum* (15th ed.). Pegem Akademi.
- Büyükoztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2011). *Bilimsel Araştırma Yöntemleri*. Pegem A Yayıncılık.
- Çapık, C., Gözüm, S., & Aksayan, S. (2018). Kültürlerarası ölçek uyarlama aşamaları, Dil ve kültür uyarlaması: Güncellenmiş rehber. *Florence Nightingale Journal of Nursing, 26*(3), 199–210.
- Chai, C. S., Hong, H. Y., & Teo, T. (2009). Singaporean and Taiwanese preservice teachers' beliefs and their attitude towards ICT: A comparative study. *The Asia-Pacific Education Researcher, 18*, 117–128.
- Clements, D. H., & Sarama, J. (2003). Strip mining for gold: Research and policy in educational technology – A response to. *Educational Technology Review, 11*(1), 7–69.

- Cordes, C., & Miller, E. (2000). *Fool's gold: A critical look at computers in childhood. Alliance for Childhood*. Retrieved June 7, 2023, from http://www.allianceforchildhood.net/projects/computers/computers_reports.htm
- Daniel, S. J. (2020). Education and the COVID-19 pandemic. *Prospects*, 49(1), 1–6. <https://doi.org/10.1007/S11125-020-09464-3>
- Dong, C., Cao, S., & Li, H. (2020). Young children's online learning during COVID-19 pandemic: Chinese parents' beliefs and attitudes. *Children and Youth Services Review*. <https://doi.org/10.1016/j.childyouth.2020.105440>
- Erdem, E., & Demirel, Ö. (2007). Teacher self-efficacy belief. *Social Behavior and Personality*, 35(5), 573–586. <https://doi.org/10.2224/SBP.2007.35.5.573>
- Erdogan, T. (2011). Factors that influence preservice teachers' ICT usage in education. *European Journal of Teacher Education*, 34(4), 483–499.
- Ertmer, P. (2005). Teacher pedagogical beliefs: The final Frontier in our quest for technology integration. *Educational Technology Research and Development*, 53(4), 25–39.
- Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, 42(3), 255–284.
- Flanagan, L., & Jacobsen, M. (2003). Technology leadership for the twenty-first century. *Principal Journal of Educational Administration*, 41(2), 124–142.
- Frederick, G. R., Schweizer, H., & Lowe, R. (2006). After the inservice course: Challenges of technology integration. *Computers in the Schools*, 23, 73–84.
- Gayatri, M. (2020). The implementation of early childhood education in the time of Covid-19 pandemic: A systematic review. *Humanities & Social Sciences Reviews*, 8(6), 46–54. <https://doi.org/10.18510/hssr.2020.866>
- Gialamas, V., & Nikolopoulou, K. (2010). In-service and preservice early childhood teachers' views and intentions about ICT use in early childhood settings: A comparative study. *Computers & Education*, 55(1), 333–341.
- Gialamas, C., Nikolopoulou, C., & Manesis, D. (2008). Views and intentions on preschool integration and use of ICT in early childhood education. *Integration and Use of ICT in Preschool Education*, 53(7), 369–378.
- Govender, D. W., & Govender, I. (2009). The relationship between information and communications technology (ICT) integration and teachers' self-efficacy beliefs about ICT. *Education as Change*, 13(1), 153–165. <https://doi.org/10.1080/16823200902943346>
- Gözüm, A. İ. C. (2022). Digital games for STEM in early childhood education: Active co-playing parental mediation and educational content examination. In S. Papadakis & M. Kalogiannakis (Eds.), *STEM, robotics, mobile apps in early childhood and primary education* (Lecture notes in educational technology). Springer. https://doi.org/10.1007/978-981-19-0568-1_21
- Gözüm, A. İ. C., & Demir, Ö. (2021). Technological pedagogical content knowledge self-confidence of prospective preschool teachers for science education during the COVID-19 period: A structural equational modelling. *International Journal of Curriculum and Instruction*, 13(1), 712–742.
- Gözüm, A. İ. C., & Kandır, A. (2021). Digital games pre-schoolers play: Parental mediation and examination of educational content. *Education and Information Technologies*, 26(3), 3293–3326.
- Gözüm, A. İ. C., Metin, Ş., Uzun, H., & Karaca, N. H. (2022a). Developing the teacher self-efficacy scale in the use of ICT at home for preschool distance education during Covid-19. *Tech Know Learn*. <https://doi.org/10.1007/s10758-022-09616-8>
- Gözüm, A. İ. C., Papadakis, S., & Kalogiannakis, M. (2022b). Preschool teachers' STEM pedagogical content knowledge: A comparative study of teachers in Greece and Turkey. *Frontiers in Psychology*, 13, 996338. <https://doi.org/10.3389/fpsyg.2022.996338>
- Gürbüz, S., & Şahin, F. (2018). *Sosyal Bilimlerde Araştırma Yöntemleri* (5th ed.). Seçkin Yayıncılık.
- Hambleton, R. K., & Patsula, L. N. (1999). *Increasing the validity of adapted tests: Myths to be avoided and guidelines for improving test adaptation practices*.

- Harding, R. D. (2012). Policy brief: Quality management and assurance in ICT-integrated pedagogy. In UNESCO Institute for Information Technologies in Education (Ed.), *Policy brief*. UNESCO Institute for Information Technologies in Education.
- Hatzigianni, M., & Margetts, K. (2012). 'I am very good at computers': Young children's computer use and their computer self-esteem. *European Early Childhood Education Research Journal*, 20(1), 3–20.
- Hooper, D., Coughlan, J., & Mullen, M. (2008, September). Evaluating model fit: a synthesis of the structural equation modelling literature. In 7th European Conference on research methodology for business and management studies (Vol. 2008, pp. 195–200).
- Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, 6(1), 1–55.
- Jack, C., & Higgins, S. (2019). Embedding educational technologies in early years education. *Research in Learning Technology*, 27, 2033.
- Johnson, R. B., & Christensen, L. B. (2004). *Educational research: Quantitative, qualitative, and mixed approaches*. Allyn and Bacon. <https://doi.org/10.3102/0013189X033007014>
- Jöreskog, K. G., & Sörbom, D. (1993). LISREL 8: Structural equation modeling with the SIMPLIS command language. Scientific Software International; Lawrence Erlbaum Associates, Inc.
- Kabadayı, A. (2006). Analyzing preschool student teachers' and their cooperating teachers' attitudes towards the use of educational technology. *TOJET: The Turkish Online Journal of Educational Technology*, 5(4), 3–10.
- Kalaycı, S. (2008). SPSS Applied multivariate statistics techniques. Ankara: Asil publication and distribution.
- Kartal, G., & Guven, D. (2006). The place and role of computers in preschool education. *Bogazici Faculty of Education Journal*, 23(1), 19–34.
- Kerckaert, S., Vanderlinde, R., & van Braak, J. (2015). The role of ICT in early childhood education: Scale development and research on ICT use and influencing factors. *European Early Childhood Education Research Journal*, 23(2), 183–199.
- Kim, J. (2020). Learning and teaching online during Covid-19: Experiences of student teachers in an early childhood education practicum. *International Journal of Early Childhood*, 52(2), 145–158. <https://doi.org/10.1007/s13158-020-00272-6>
- Kindergarten Curriculum. (2011). *Part 2. Learning domains*. <https://drive.google.com/file/d/0BxM0yUGj0IrDNDU1MDY5NGEtODJkYy00ZGZkLTgxY2QtNjc2MjQzYjEwNjly/view>
- Koehler, M., Mishra, P., Kereluik, K., Shin, T. S., Graham, C. R., et al. (2014). The technological pedagogical content knowledge framework. In J. M. Spector (Ed.), *Handbook of research on educational communications and technology* (pp. 101–111). Springer.
- Kol, S. (2012a). Development of attitude scale devoted to the usage of technology in preschool education. *Kastamonu Education Journal*, 20(2), 543–554.
- Kol, S. (2012b). Evaluating the opinions of the preschool teachers on computer-assisted education. *Educational Sciences: Theory & Practice*, 12(2), 897–903.
- Konca, A. S., & Tantekin Erden, F. (2021). Digital technology (DT) usage of preschool teachers in early childhood classrooms. *Journal of Education and Future*, 19, 1–12. <https://doi.org/10.30786/jef.627809>
- Konca, A. S., Özel, E., & Zelyurt, H. (2016). Attitudes of preschool teachers towards using information and communication technologies (ICT). *International Journal of Research in Education and Science (IJRES)*, 2(1), 10–15.
- Korkmaz, F., & Ünsal, S. (2016). An investigation of preschool teachers' perceptions on the concept of "technology". *Mustafa Kemal University Journal of Graduate School of Social Sciences*, 13(35), 194–212.
- Kundu, A., & Bej, T. (2020). Ingestion and integration of ICTs for pedagogy in Indian private high schools. *E-Learning and Digital Media*. Advance online publication. <https://doi.org/10.1177/2042753020957493>.
- Künsting, J., Neuber, V. & Lipowsky, F. (2016). Teacher self-efficacy as a long-term predictor of instructional quality in the classroom. *Eur J Psychol Educ* 31, 299–322. <https://doi.org/10.1007/s10212-015-0272-7>

- Lavidas, K., Katsidima, M.-A., Theodoratou, S., Komis, V., & Nikolopoulou, K. (2021). Preschool teachers' perceptions about TPACK in Greek educational context. *Journal of Computers in Education*, 8(3), 395–410. <https://doi.org/10.1007/s40692-021-00184-x>
- Leung, W. M. (2010). *Young children's learning with information and communication technologies in Hong Kong kindergartens*. Victoria University.
- Lindahl, M. G., & Folkesson, A. M. (2012). ICT in preschool: Friend or foe? The significance of norms in a changing practice. *International Journal of Early Years Education*, 20(4), 422–436.
- Manessis, D. (2011). *Early childhood post-educated teachers' views and intentions about using digital games in the classroom*. In Proceedings of the 5th European Conference on Games Based Learning (pp. 753–758). The National and Kapodistrian University of Athens.
- Marsh, H. W., & Hau, K. T. (1996). Assessing goodness of fit: Is parsimony always desirable?. *The journal of experimental education*, 64(4), 364–390.
- Moos, D. C., & Azevedo, R. (2009). Learning with computer-based learning environments: A literature review of computer self-efficacy. *Review of Educational Research*, 79(2), 576–600.
- Morris, D. B., Usher, E. L., & Chen, J. A. (2017). Reconceptualizing the sources of teaching self-efficacy: A critical review of emerging literature. *Educational Psychology Review*, 29(4), 795–833.
- Murphy, K.R., & Davidshover, C.O.. (1994). Psychological testing: Principles and applications. 3rd ed. Englewood Cliffs, NJ. Prentice-Hall.
- NAEYC & Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College. (2012). *Technology and Interactive media as tools in early childhood programs serving children from birth through age 8. joint position statement*. NAEYC. www.naeyc.org/content/technology-and-young-children
- NAEYC/National Association for the Education of Young Children. (2012). *Technology and interactive media as tools in early childhood programs serving children from birth through age 8*. https://www.naeyc.org/sites/default/files/globallyshared/downloads/PDFs/resources/topics/PS_technology_WEB.pdf
- Nikolopoulou, K., & Gialamas, V. (2009). Investigating preservice early childhood teachers' views and intentions about integrating and using computers in early childhood settings: Compilation of an instrument. *Technology, Pedagogy and Education*, 18(2), 201–219.
- Nikolopoulou, K., & Gialamas, V. (2015). ICT and play in preschool: Early childhood teachers' beliefs and confidence. *International Journal of Early Years Education*, 23(4), 409–425.
- Nkula, K., & Krauss, K. E. (2014). *The integration of ICTs in marginalized schools in South Africa: Considerations for understanding the perceptions of in-service teachers and the role of training*. In International Development Informatics Association (IDIA) conference (pp. 3–5). <http://www.developmentinformatics.org/conferences/2014/papers/20-NkulaKirsten.pdf>
- Oye, N. D., Lahad, N. A., & Rahim, N. (2014). The history of UTAUT model and its impact on ICT acceptance and usage by academicians. *Education and Information Technologies*, 19(1), 251–270.
- Palaiologou, L. (2016). Children under five and digital technologies: Implications for early years pedagogy. *European Early Childhood Education Research Journal*, 24(1), 5–24.
- Palak, D., & Walls, R. T. (2009). Teachers' beliefs and technology practices: A mixed-methods approach. *Journal of Research on Technology in Education*, 41, 417–441. <https://doi.org/10.1080/15391523.2009.10782537>
- Pange, J. (2008). *Educational technology*. PBS Theodorides.
- Papadakis, S., & Kalogiannakis, M. (2020). A research synthesis of the educational value of self-proclaimed mobile educational applications for young age children. In S. Papadakis & M. Kalogiannakis (Eds.), *Mobile learning applications in early childhood education* (pp. 1–19). IGI Global. <https://doi.org/10.4018/978-1-7998-1486-3.ch001>
- Papadakis, S., Gözümlü, A. İ. C., Kalogiannakis, M., & Kandır, A. (2022). A comparison of Turkish and Greek parental mediation strategies for digital games for children during the COVID-19 pandemic. In S. Papadakis & M. Kalogiannakis (Eds.), *STEM, robotics, mobile apps in early childhood and primary education* (Lecture notes in educational technology). Springer. https://doi.org/10.1007/978-981-19-0568-1_23

- Pavithra, D. T., & Kumar, P. (2012). *Teacher self efficacy*. Lap Lambert.
- Peeraer, J., & Van Petegem, P. (2011). ICT in teacher education in an emerging developing country: Vietnam's baseline situation at the start of 'the year of ICT'. *Computers & Education*, 56(4), 974–982.
- Pelgrum, W. J., & Law, N. (2003). *ICT in education around the world: Trends (Problems and prospects (fundamentals of educational planning))* (Vol. 77). UNESCO-IIEP.
- Petrogiannis, K. (2010). The relationship between perceived preparedness for computer use and other psychological constructs among kindergarten teachers with and without computer experience in Greece. *Journal of Information Technology Impact*, 10(2), 99–110.
- Sang, G., Valcke, M., Braak, J., Tondeur, J., & Zhu, C. (2011). Predicting ICT integration into classroom teaching in Chinese primary schools: Exploring the complex interplay of teacher-related variables. *Journal of Computer Assisted Learning*, 27, 160–172.
- Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of psychological research online*, 8(2), 23–74.
- Schwab, S. (2019). Teachers' student-specific self-efficacy in relation to teacher and student variables. *Educational Psychology*, 39(1), 4–18. <https://doi.org/10.1080/01443410.2018.1516861>
- Scrimshaw, P. (2004). *Enabling teachers to make successful use of ICT: Coventry*. British Educational Communications and Technology Agency.
- Seçer, İ. (2015). *Psikolojik Test Geliştirme ve Uyarlama Süreci*. Anı Yayıncılık.
- Şeker, H., & Gençdoğan, B. (2014). *Psikolojide ve Eğitimde Ölçme Aracı Geliştirme* (2nd ed.). Nobel Yayınevi.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.
- Simsar, A., & Kadim, M. (2017). Okul öncesi öğretmenlerinin bilişim teknolojilerini kullanma durumları ve bunun öğretime etkisi. *Kilis 7 Aralık Üniversitesi Sosyal Bilimler Dergisi*, 7(14), 127–146.
- Slutsky, R., Kragh-Müller, G., Rentzou, K., Tuul, M., Gol Guven, M., Foerch, D., & Paz-Albo, J. (2021). A cross-cultural study on technology use in preschool classrooms: Early childhood teacher's preferences, time-use, impact and association with children's play. *Early Child Development and Care*, 191(5), 713–725. <https://doi.org/10.1080/03004430.2019.1645135>
- Straub, E. T. (2009). Understanding technology adoption: Theory and future directions for informal learning. *Review of Educational Research*, 79(2), 625–649.
- Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics*, 4th Ed. Boston: Allyn & Bacon.
- Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6, pp. 497–516). Boston, MA: pearson.
- Taş, Y., Eminoglu, S., Atila, G., Yildiz, Y., & Bozkurt, U. (2021). Teachers' self-efficacy beliefs and opinions about distance education during the COVID-19 pandemic. *The Turkish Online Journal of Distance Education*, 22(4), 229–253. <https://doi.org/10.17718/TOJDE.1002868>
- Tezci, E. (2011). Factors that influence preservice teachers' ICT usage in education. *European Journal of Teacher Education*, 34, 483–499.
- Toki, E. I., & Pange, J. (2006). *A comparative study of two learning methods: Collaborative learning versus nearest neighbor learning*. In EISTA 2006 Proceedings, Orlando.
- Toki, E. I., Pange, A., & Pange, J. (2009). The necessity of ICT literacy in undergraduate educational departments students. In A. Méndez-Vilas, A. Solano Martín, J. A. Mesa González, & J. Mesa González (Eds.), *Research, reflections and innovations in integrating ICT in education*. Badajoz.
- Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing preservice teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers and Education*, 59, 134–144. <https://doi.org/10.1016/j.compedu.2011.10.009>
- Tsai, C.-C., & Chai, C. S. (2013). The “third”-order barrier for technology integration instruction: Implications for teacher education. *Australasian Journal of Educational Technology*, 28(6), 1057–1060. <https://doi.org/10.14742/ajet.810>

- Tsitouridou, M., & Vryzas, K. (2003). Early childhood teachers' attitudes towards computer and information technology: The case of Greece. *Information Technology in Childhood Education Annual, 1*, 187–207.
- Tsitouridou, M., & Vryzas, K. (2004). The prospect of integrating ICT into the education of young children: The views of Greek early childhood teachers. *European Journal of Teacher Education, 27*(1), 29–45.
- Turkish Ministry of National Education (MoNE). (2013). *Preschool education program*. Ministry of National Education Publishing.
- Weigold, A., & Weigold, I. K. (2021). Measuring confidence engaging in computer activities at different skill levels: Development and validation of the brief inventory of technology self-efficacy (BITS). *Computers & Education, 169*, 104210.
- Wilson-Strydom, M., & Thompson, J. (2005). *Understanding ICT integration in South African classrooms*. http://www.shoolnet.org.za/research/Wilson-Strydom_Thomson.doc
- YILDIRIM, Y. (2021). A Sequence of distance education lasting 6 years in the ottoman state: Literature lessons from Ebuzziya Tevfik Bey to his Son Velid. *Vakanüvis - Uluslararası Tarih Araştırmaları Dergisi, 6*(1), 441–459. <https://doi.org/10.24186/vakanuvis.880434>
- Yurt, Ö., & Cevher-Kalburan, N. (2011). Early childhood teachers' thoughts and practices about the use of computers in early childhood education. *Procedia Computer Science, 3*, 1562–1570.

Chapter 2

Benefits, Challenges and Opportunities of Using Computer-Assisted Instruction in Mathematics Education



Farouq Sessah Mensah  and Ernest Ampadu 

Introduction

The importance of education for both personal and national development cannot be underestimated. Human capital development through education and training has become the hallmark for enhancing the quality of life and an essential means of addressing the increasingly fierce competitiveness of the citizenry (Chou, 2012). Quality education at all levels is a significant concern among educators and other stakeholders in the education sector. UNESCO's sustainable development goals, especially SDG 4, call for ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all by 2030 (UNESCO, 2017). Like other subjects, mathematics plays a crucial role in the school curriculum because of its pivotal role in other subjects (Jones, 2000). However, learners' performance in mathematics in most countries has been plummeting over the years, evident in national and international assessments (Henrekson & Jävervall, 2016).

Many researchers (e.g. Abd-Kadir & Hardman, 2007; Asami-Johansson et al., 2020; Hemmi et al., 2021; Madej, 2022) have argued that how mathematics is conceived, taught, and learned has affected many students' performance and interest. Most students need help appreciating the utilitarian motives of the different but interrelated mathematical concepts and skills they learn in their respective classrooms. This does not contribute to the realization of their full potential. For

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example, Madej (2022), Usiskin (1995), and others attested to the vital role that competence in algebraic concepts plays in the learning of other mathematical concepts and their application to other fields. Students' poor mathematics performance has been attributed to different but interrelated factors for which teachers' pedagogical content knowledge is considered one of the most critical factors. However, despite teachers' pedagogical content knowledge's important role in delivering practical lessons, research by Lindvall et al. (2018) and others has shown that this has little or no impact on student achievement. Some researchers have suggested critically analysing teacher quality, supervision, and teaching and learning materials (Cai et al., 2005; Hemmi et al., 2013). To address this problem, many classrooms have implemented various creative and transformative teaching approaches (Lotz-Sisitka et al., 2015). Researchers, teachers, and other agents in the educational sector are also advocating for a paradigm shift in how mathematics is taught and learned. This has necessitated a paradigm shift from a teacher-centred perspective, where the teacher is seen as the custodian of knowledge and students play a passive role in the teaching-learning process to a more student-centred approach.

However, it is essential to note that the demands of modern educational environments require high-quality mathematics instruction (Corey et al., 2010; Munter, 2014; Rosenquist et al., 2015), in which instructional technology is integral. Consequently, we critically examine how integrating computer-assisted instruction (CAI) has influenced mathematics education in general and, more specifically, students' performance and learning experiences based on the fourth industrial revolution (4IR) principles. The fourth industrial revolution has brought many changes in almost every sector of the economy, introducing and integrating technology into our daily activities. The educational sector has, over the years, experienced an expansion of integrating instructional technologies to aid teaching and learning (Selwyn et al., 2020). As highlighted above, the evolution of digital learning for Industry 4.0 has brought many changes in how we teach, how students learn, and assessment practices.

Many countries and schools have implemented several technologically inclined curricula and activities to enhance student's learning experiences. A typical example of this is the e-learning initiative (European Commission, 2000), which has improved the quality of learning by increasing learners' access to ICT facilities for learning. Theoretical and technological advancements have led to the adoption of constructionist teaching strategies in many classrooms. Constructionists, like constructivism, emphasize the importance of learners' active participation in teaching-learning and argue for integrating appropriate instructional technologies to help students develop conceptual understanding. However, despite these innovations, there are still some long-standing traditions, such as the compartmentalization of knowledge in the curriculum and the use of high-stakes and standardized testing, which remain unchanged in most mathematics classrooms (Selwyn et al., 2020).

The tension between the subject of mathematics and mathematics education continues to be an issue of concern in our quest to help students develop conceptual understanding. As a result, there is a need for a critical look at the curriculum and syllabus designing process, particularly emphasizing the learning outcomes of

courses, activities, and assessment procedures. We should also consider alternative teaching and assessment modes, such as hybrid and digital tools, as these will help harness our readiness to implement CAI in mathematics classrooms to help improve students' learning experiences and performance.

In this chapter, selected concepts and theoretical backgrounds for CAI in mathematics classrooms are presented, and these aspects are discussed from theoretical and examples of empirical studies that have examined the concept of CAI from different contexts. Based on the purpose of this position paper, a clarification of the concept of CAI in mathematics education is first made. Through a review of meta-analysis studies, we offer evidence of the positive effect of CAI on students' mathematics learning outcomes. In addition, based on the current state of mathematics education across different contexts, we critically analyse different instructional design frameworks used in the CAI environment and contribute to the debate on using CAI in mathematics.

Meaning of Computer-Assisted Instruction

Computers have become an integral part of the twenty-first-century classroom, and many traditional teaching methods have been updated to integrate computers into core teaching practices. While using computers in the classroom is increasingly common, not all such uses may be considered CAI. However, irrespective of how dynamic the concept of CAI may be, its core tenet is computer-based instruction. According to Edutech202 (2012), CAI is a form of automated teaching in which a computer delivers an interactive curriculum to the student. CAI uses computers to mediate the information flow between the instructor and the student (Rushby, 2019). Sharma (2017) explains CAI as an interactive instructional approach using a computer to present the instructional material and monitor learning.

Computer-assisted instruction (CAI), computer-assisted learning (CAL), computer-based-education (CBE), computer-based instruction (CBI), computer-based learning (CBL), computer-managed instruction (CMI), e-learning technology (e-LT), and many other terms are used to describe educational uses of computers, where either instruction is delivered to a passive student via a computer programme or the computer serves as the foundation for an interactive, dynamic, and personalized learning experience. CAI is an instructional strategy that uses a response entry mechanism and a computer-controlled display to promote engagement and active participation in teaching-learning through the strategic use of text, images, sound, and video.

CAI is considered a concept in education with unprecedented significance in classrooms (Xie et al., 2020). CAI can be used for various subjects, ages, grade levels, and forms of education and is intended to complement traditional classroom learning. CAI is flexible and can be used independently or with more conventional teaching approaches. However, Christmann et al. (1997) empirically demonstrate that combining traditional teaching approaches with CAI is the most effective way

to improve student's learning outcomes. The emergence and widespread usage of artificial intelligence (AI), particularly in education, has led to the introduction of intelligent tutoring systems (ITS), a form of CAI but in a more advanced form. ITS are computer programmes powered by AI that can mimic and carry out the functions of a human teacher. AI-based tutoring systems are quickly gaining popularity as an instructional approach in the twenty-first century as the world progressively enters the 4IR. However, the scope of this chapter is within the CIA. We consider CAI as a part of the didactical situations organized by teachers.

Objectives of Computer-Assisted Instruction

The primary objective of the CAI is to provide students with individualized instruction tailored to their specific learning needs. CIA aims to accommodate the diverse learning needs students bring to the classroom. Additionally, CAI is developed to help learners overcome their learning difficulties, improve their performance, and shield them from the potentially damaging impacts of a rote-memory-oriented education. CIA serves both cognitive and psychological learning needs. The objective of the CIA is grounded in communication theory, learning theory, system theory, and audiovisual and media theory.

Features of Computer-Assisted Instruction

One of the unique features of CAI is its capability to initiate customized interactions with learners. The CIA model involves a mutual exchange of information between the learner and the computer. The mode of communication is based on a stimulus-feedback signal flow. The computer comes with preloaded instructional programmes that teach, guide, oversee, and evaluate learners until they reach a specific level of proficiency. The computer platform should be interactive, not just for retrieving information and solving problems. It should be able to capture and store each student's response. Based on the stored data, the system can decide which lessons to provide after each session, how long to spend on a question, and the level of accuracy (Sampath et al., 1990).

CAI is a more personalized system of learning (Croy, 1988). Students can proceed through the learning materials at their own pace without worrying about holding up the class. As a result, learners are accessible from the anxiety of staying up with their peers and can instead concentrate on the content at hand (Van Scoyoc, 2003). CAI empowers students to take on increasing responsibility for choosing, managing, and evaluating their learning activities. The computer can track each student's progress and adapt the learning experience to meet their learning style and needs, whether through a game, interactive demonstration, or assessment. CAI makes differentiated instruction simpler than traditional approaches to teaching

(Ertmer, 1999). A more individualized approach produces increased engagement and improved learning outcomes. In addition to a more personalized learning system, CAI provides countless possibilities for practice. With CAI, learners get as much practice as they need because digital exercises and questions can be created quickly, easily, and in various formats. Learners with lesser aptitudes do not slow down students with higher aptitudes, and students with lower aptitudes are not coerced into moving on before they are ready, because they all get the chance to practice at their own pace.

Feedback is real time for teachers and students (Gersten et al., 2009). CAI gives learners instantaneous responses, facilitating the speedy detection and correction of errors. CAI programmes provide immediate feedback to students by not only listing errors but also offering additional insights for improvement. It also maintains thorough records of development and reporting systems for easy access. Students can speed through their coursework by immediately gaining insight into and correcting any errors they may have made. Teachers also benefit from this, because they can use the data to improve their instruction and assess student performance.

Online or offline CAI has greater interactivity and engagement (Forbringer & Weber, 2014). Learner engagement is maintained and sustained through the different activities inherent in CAI. Students are more likely to thrive when presented with interesting and different learning opportunities, even more so than conventional books and lectures. Visual and auditory interfaces in the classroom can be more engaging and stimulating. CAI provides a way for learners who need help focusing on maintaining their focus. The likelihood of boredom is significantly minimized because CAI uses many diverse ways.

CIA breaks down complex information into smaller, more easily digestible sections for students' convenience. To help learners appreciate that they are making progress, CAI offers information in a highly structured way with small markers. Microlearning is a term used to describe this type of incremental learning, because it typically consists of short learning tasks (Dolasinski & Reynolds, 2020). Microlearning programmes, like Duolingo or Khan Academy, have entirely revolutionized the app market. CAI offers learning opportunities for those with limited learning time or attention spans.

Instructional Modes in Computer-Assisted Instruction

The instructional modes in CAI have differed, just as there have been varying definitions of CAI. Generally, CAI delivery modes have been classified into drill and practice, tutorials, dialogue, simulation, problem-solving, educational games, discovery, inquiry mode, author mode, modelling, and LOGO.

Drill and practice are commonly used modes of delivery of CAI due to their simplicity. Because of their repetitive character, drill-and-practice activities represent a traditional, behaviourist approach that focuses on acquiring basic abilities or revisiting previously taught content. However, CAI's drills and practice are more

engaging for learners than working out of a workbook. In a typical drill-and-practice activity, learners are given a question to answer, followed by an evaluation of their response and feedback. Lower-order cognitive skills are generally covered by drill-and-practice mode of delivery of CAI. A tracking device is usually used in the drill-and-practice mode of delivery of CAI so that students and teachers may keep track of their development.

Furthermore, drill-and-practice exercises provide users with encouraging sounds and other elements to assist them in progressing at their own pace. For a drill-and-practice activity to be successful, according to Schwier and Misanchuk (1993), there should be a progressive increase in the “types, amount, and layers of stimuli and feedback presented” (p. 20). The goal of a well-designed drill-and-practice activity should be to deepen the learner’s grasp of a concept through repeated exposure to the materials.

In a tutorial mode of delivering CAI, the computer takes on the didactic role of the teacher. For instance, *Mavis Beacon Teaches Typing* is a tutorial programme that helps learners improve their touch-typing skills. While drill-and-practice exercises are helpful, tutorials take learning to the next level by guiding students through acquiring knowledge. There is typically a predetermined format and sequence for a tutorial. An introduction is given that summarizes the topics that will be discussed during the session. The computer then analyses the learner’s responses to questions and provides feedback. Tutorials provide constructive feedback on answering the problem correctly rather than simply supplying more practice problems. The cycle is completed once the learner or the programme decides to finish the class. The lesson ends with a summary. Online interactive learning can benefit from tutorials since they offer a range of learning opportunities to motivate learners through digital media. Individualized learning in a tutorial allows students to move at their own pace while still receiving many opportunities for practice, error correction, and concept clarification (Schwier & Misanchuk, 1993).

In addition to making up for lost time, reviewing previously covered content, and correcting mistakes, tutorials can be utilized to instruct absent learners (Merrill et al., 1992). Alessi and Trollip (1991) assert that tutorials are useful for “presenting factual information, for learning rules and principles, or for learning problem-solving strategies” (p.17). Students in geographically dispersed, smaller schools or classes with insufficient enrolment to warrant hiring a subject-matter expert may benefit from a tutorial, because it can serve as a source of instruction without a qualified instructor in the given subject area (Alessi & Trollip, 1991). Although beneficial for individual learning, tutorials need to facilitate teamwork.

Dialogue as a mode of delivering CAI is a complex communication between the student and the computer. The student engages the machine in conversation by asking questions and responding, to which the computer programme responds appropriately. However, to write the programme on the computer terminal closest to where the student is receiving instruction, the computer must be developed to understand the learner’s words and the meaning of the question they are asking (Soe et al., 2000).

By creating a virtual version of a real-world scenario, a simulation mode of delivering CAI allows students to experiment with different approaches. Simulations approximate reality while avoiding the costs and dangers of the real world (Granlund et al., 2000). The use of simulation helps bring theoretical ideas into focus. Simulations serve as a bridge between learners' idealized versions of the world and reality. In the twenty-first century, simulations have been created for educational and recreational use within and outside the classroom. Through multimedia, simulations represent and connect enormous amounts of data (Alessi & Trollip, 1991).

The problem-solving approach to delivering CAI emphasizes the processes used to solve a problem more than the solution itself. In this context, students employ software that prompts them to think about multiple potential approaches to a problem. Problem-solving is one of the problematic modes of delivering CAI. The problem-solving approach used in CAI helps learners build problem-solving skills while enhancing higher-order thinking skills (Renshaw et al., 1998).

An educational game of delivering CAI is an activity in which players follow rules that differ from real life to achieve challenging goals (Zeng et al., 2020). Differentiating between educational games, drills and practice, and simulations can be challenging practically. Thus, a game's educational value is debatable. It must have opportunities to hone academic skills to be considered an educational game. The purpose of educational games is to increase student engagement with course content. The assumption underlying educational games is that players already know the content and often set strict time limits to spur players to think quickly and take decisive action.

The discovery mode of delivering CAI offers a comprehensive repository of materials related to a subject area or curriculum. Discovery mode presents an analytical, comparative, inferential, and evaluative challenge to learners based on their information exploration (Sharma, 2017). The inductive method of instruction and learning is used in discovery. To resolve a specific challenge, the learner is encouraged to go through trial and error.

The author's mode of delivering CAI creates collections of materials for a learner to support instruction (Splittgerber, 1979). The authoring mode relies on students accessing, exploring, and referring to a thoughtfully chosen, organized, and improved set of materials for optimum impact in delivering CAI. All other elements, such as the learning objectives, assessment, and activities, are coordinated with the most efficient learning materials. The authoring mode could be sentencing forms with blanks that must be filled with individual or group words when creating concept learning materials.

Similar to the simulation mode, the modelling mode of delivering the CAI helps students learn by allowing them to engage with a digital model of a real-world system or phenomenon (Balacheff & Kaput, 1996). The learner builds the analogue in modelling mode instead of simulation, where the teacher specifies the analogue. The learner must properly "teach" the computer about the rules for the computer to accurately replicate the real-world system under specified conditions and predict the real-world system's behaviour under novel settings. The learner acquires knowledge through this procedure and demonstrates competency in modelling.

LOGO mode of delivery CAI is an educational programming language developed to counteract the complexities of using more advanced programming languages like BASIC and PASCAL in learning (Abelson et al., 1974). Different tasks can be carried out by programmes written in LOGO and across different curriculums. The turtle geometry in LOGO is a feature that helps learners learn computer programming. The learner can use it to draw anything they want, including geometrical shapes. Unlike other programming languages, LOGO is commonly taught in a child-centred, open-ended manner. By testing hypotheses, learners who use LOGO understand how programming functions. LOGO applications have been proven to affect problem-solving and overall cognitive abilities considerably (Psycharis & Kallia, 2017).

Design of Computer-Assisted Instruction in Mathematics Education

Educators and teachers have adapted different strategies for integrating technology into varying lesson stages in designing CAI in mathematics. Researchers (Genlott & Grönlund, 2016, p. 69) have argued that “while technology in itself does not lead to improvement of student results, it may well be used to reinforce pedagogic factors that have been shown to have a positive impact”. That is, the educational benefits of CAI cannot be underestimated. The ever-changing needs and aspirations of society regarding what mathematical concepts students should learn and how they should learn these concepts call for new ways of designing lessons. For this reason, many researchers have advocated using a CAI to provide instructional content with particular emphasis on content and interaction with CAI that causes learners to actively participate in the learning process and change their experiences and performances (Seo & Woo, 2010). The demand placed on teachers to integrate instructional technologies into their core teaching practices has prompted researchers in the field of education to rethink the theoretical frameworks for teacher knowledge, especially for integrating technology (Niess, 2008). The technological pedagogical content knowledge (TPACK) framework is the most common framework for developing teacher knowledge despite its fuzzy boundaries, concealed complexities, and lack of applicability in classroom practice. The work of Shulman (1986) provides the evolution of the TPACK framework with the view that effective instructional design goes beyond the individual teacher’s pedagogical content knowledge. The TPACK model shows the critical roles of the teacher’s pedagogical content and technological knowledge in developing lessons that help develop students’ conceptual understanding. As highlighted above, merely integrating technology into a mathematics lesson may not necessarily lead to students’ conceptual understanding and improved learning experiences and achievement.

Niess et al. (2009) have outlined a five-stage developmental process for integrating technology into teaching mathematics for better conceptual understanding. The

process involves recognizing, accepting, adapting, exploring, and advancing. Hence, teachers must consciously understand how to integrate specific or different technologies into their teaching. When deciding which instructional technology to use for a mathematics lesson, it is essential to carefully analyse how it can best be integrated for maximum benefit. This decision should not be left to chance. Hence, the teacher needs to examine the five-step process Field Niess et al. (2009) identified to determine whether the instructional technology is worth integrating. Despite the innovative nature of the TPACK framework and the five steps provided by Niess et al. (2009), research by Rakes et al. (2022) posit the need to take into consideration contextual factors, such as class size, resources, culture, and environment, as this could affect the effective implementation of the framework.

Teachers use instructional technology in the classroom affects instructional strategies, student learning, and curriculum objectives by replacing, amplifying, or transforming current lessons and activities (Hughes et al., 2006). Researchers and teachers in the field of mathematics education have also employed other technology integration frameworks, including RAT (replace, amplify, and transform), SAMR (substitution, augmentation, modification, and redefinition), PIC-RAT (passive, interactive, creative-replace, amplify, and transform), among others, in a CAI environment. Mathematics teachers can use the RAT framework as a model and assessment tool to consider critically how their use of CAI in the classroom promotes meaningful student learning. SAMR, as an instructional technology integration framework, assists and directs teachers as they create and implement technology-based digital learning experiences (Hamilton et al., 2016). There are several parallels and distinctions between RAT and SAMR. The terms “substitution” in SAMR and “replacement” in RAT refer to technology that only replaces or substitutes for earlier usage without functionally improving efficiency. The terms “redefinition” in SAMR and “transformation” in RAT address technology that enables teachers and students to learn in novel, hitherto unimaginable ways. The SAMR and RAT frameworks can assist teachers in answering the question, “How has my use of instructional technology altered my teaching?” It is a less valuable use of instructional technology if it replaces or substitutes a previous practice.

The centre letters in SAMR and RAT distinguish them. RAT’s amplification is divided into augmentation and modification in SAMR. All these division deals with instructional technology that functionally enhances what is occurring in the mathematics classroom. In contrast, it is a more practical use of instructional technology if it alters or redefines classroom practice. PIC-RAT presupposes that teachers should always enquire about any instructional technology used in their classrooms with these two fundamental questions: (1) How does the student interact with technology? (PIC) And (2) how does the employment of technology by the teacher affect conventional practice? (RAT) (Hughes et al., 2006).

Just like TPACK, we critique RAT, SAMR, and PIC-RAT. We critique SAMR and RAT for failing to reflect learning accurately. Rather than SAMR and RAT being the key to unlocking the higher levels of Bloom’s taxonomy, instructional technology could potentially become a barrier to learning if a teacher constantly strives to “redefine” or “transform” learning. SAMR and RAT are helpful ideas for

discussing integrating instructional technologies in the mathematics classroom. However, they should refrain from leading mathematics teachers to believe that they must constantly redefine how they might improve students' meaningful learning. In the PIC-RAT framework, there is misunderstanding surrounding creative use, transformative practice, adaptability to various educational contexts, evaluations that go beyond activity level, and disconnect with student learning outcomes. Instructional technology in the mathematics classroom is most effective for a specific purpose, significantly when it enriches the learning experience and has a solid connection to the learning objectives. Regardless of the instructional technology integration framework chosen in a CAI environment, mathematics teachers must ensure they can use it to support learning objectives and best mathematics teaching practices by understanding it and knowing how to use it to improve or transform meaningful learning experiences and integrate it quickly and seamlessly within the context of mathematics education.

Computer-Assisted Instruction and Students' Learning in Mathematics

There has been much research into how computers and other instructional technologies are used to enhance meaningful mathematics teaching and learning. Over the past 30 years, many meta-analysis studies have been conducted on CAI's impact on students' mathematics learning outcomes. Despite differences in the effect size, the meta-analyses have consistently demonstrated that CAI significantly improved students' mathematics learning outcomes. One possible explanation for the discrepancies in effect sizes is that different reviews had varying criteria for what was considered eligible for inclusion. Table 2.1 displays the CAI meta-analyses we extracted connected to mathematics learning outcomes.

Students benefit significantly from CIA's integration in mathematics classrooms, because it provides learning opportunities for them to engage in complex problem-solving activities (Baker et al., 2010), conceptualizing and modelling (Tucker, 2018) and making conjectures, and collecting and recording data (Cullen et al., 2020). CAI allows teachers to tailor their lessons to each student, improving the quality of students' mathematical learning and retention (De Witte et al., 2015). Numerous studies have been conducted due to the growing interest in how different modes of delivery of CAI might enhance different aspects of mathematics education. For instance, Chang et al. (2006) discovered that using a CAI's problem-solving mode significantly improved fifth-grade students' problem-solving ability ($d = 0.78$). CAI was found to increase learners' problem-solving ability in fifth graders considerably using the "Solve Word Problems" (Fede et al., 2013). The impact of CAI can be directly attributed to integrating instructional elements that are effective in helping students learn problem-solving skills, such as schematic diagrams, strategy instruction, and instructional feedback. Also, CAI's educational

Table 2.1 Summary of CAI and students' learning outcomes in mathematics

Author(s)	Years covered	Studies included	Effect size
Kulik et al. (1985)	1967–1982	17	+0.54
Kulik and Kulik (1991)	1966–1986	9	+0.39
Becker (1992)	1977–1989	11	+0.27
Fletcher-Flinn and Gravatt (1995)	1987–1992	24	+0.32
Liao (1998)	1986–1997	5	+0.13
Liao (2007)	1983–2003	12	+0.29
Rosen and Salomon (2007)	1986–2002	31	+0.46
Slavin and Lake (2008)	1971–2006	38	+0.19
Li and Ma (2010)	1990–2006	46	+0.28
Rakes et al. (2010)	1968–2008	36	+0.16
Cheung and Slavin (2013)	1960–2011	74	+0.15
Sung et al. (2016)	1993–2013	12	+0.34
Zheng et al. (2016)	2001–2015	7	+0.16
Chauhan (2017)	2000–2016	41	+0.47
Tokac et al. (2019)	2000–2017	24	+0.13
Xie et al. (2020)	1986–2019	36	+0.38
Ran et al. (2021)	1977–2019	45	+0.56

game mode of delivery has positively impacted students' motivation in mathematics over time (Fadda et al., 2022; Okolo, 1992). Generally, CAI has been demonstrated to aid in fostering mathematics learning and is particularly beneficial for promoting higher-order skills, like critical thinking, problem-solving, conjecturing, analysis, and scientific inquiry.

Computer-Assisted Instruction Debate in Mathematics Education

CAI has been heavily scrutinized and debated since it was first proposed, with several arguments for and against it. The engagement of several stakeholders (such as learners, parents, teachers, school administration, policymakers, etc.) with often conflicting interests is one of the leading causes of this ongoing debate. Much discussion has been over whether CAI improves mathematics teaching and learning.

When used appropriately in the mathematics classroom, CAI may support the teacher in presenting materials and aid the learner in more quickly grasping the necessary concepts. When discussing the benefits of integrating instructional technology into the classroom, we point to meta-analysis studies showing improved learner achievement, engagement, and motivation due to using CAI. In the 1950s, Skinner wrote some publications outlining his viewpoint on the potential benefits of using instructional technology in teaching and learning. Skinner (1958) refers to these digital tools as “teaching machines’“. The use of CAI has been supported by

the claim that it may facilitate learners' focus more on conceptual understanding of the most challenging and complex concepts. CAI has a flexible nature that can provide personalized instruction and feedback to meet the needs of each learner.

Additionally, the frequent interaction between the teacher, system, and learner makes the learning experience interactive. We also claim that the CIA may significantly contribute to democratizing access to mathematics education by expanding educational opportunities for students from all socioeconomic backgrounds, especially those from underprivileged backgrounds. With its affordances in mind, it is worthwhile to devote significant resources to adopting CAI in mathematics classrooms. The best use of CAI is to supplement it with a traditional curriculum. This approach can help increase students' interest in a subject while enhancing their technical and informational skills, which CAI encourages.

Although CAI has many positive impacts on teaching and learning mathematics, it also has some drawbacks. Although we claim the beneficial effect of CAI on learners' achievement, it should not be seen as a silver bullet for addressing the issue of enhancing learners' academic success. Any effect on learners' learning ability would be minimal if not used effectively. We argue that CAI cannot compare to having a human instructor, because it can only respond to questions that have been programmed into it and can only teach within the parameters of its programmatic limitations. Having teachers and learners with access to computers and the Internet is a significant major hurdle. This can be especially challenging for teachers and learners from low-income backgrounds or remote areas with limited access to modern educational and technological resources.

Generally, technological advancements come at a high cost. The high cost could make acquiring and implementing CAI challenging among teachers and learners from low-income backgrounds. This is especially true when the technological resources are tailored to a specific demographic, though teachers should know that cheaper options are available. There is a danger of rapidly using technologies that could become irrelevant or outdated due to the rapid pace at which technology and content are evolving and being re-evaluated and reconceived. Due to the high cost of CAI, teachers considering their use should investigate potential alternatives or collaborate closely with programmers to ensure that the software can be updated to include new materials.

More reliance on technology poses a threat. Instead of replacing teaching and learning efforts in mathematics, CAI should supplement them. There is a threat that teachers and students will come to rely too heavily on CAI's automated features to complete routine tasks. Furthermore, some teachers might need help finding technological resources that support their lesson plans and try to change their lessons. However, the ideal scenario will be for them to seek technologies that support and enhance their lesson plans rather than the opposite. In the best situation, CAI is beneficial and enhances education but has drawbacks. CAI could become a distraction if a balance is not maintained correctly in the mathematics classroom. Learners may need help paying attention to real-time instruction when they use CAI in the mathematics classroom. It is a constant struggle for teachers of all levels to convince their students to pay attention, and when technology is involved, a distraction for

learners is made even more straightforward. To support teachers and learners in mathematics education, teachers should balance utilizing CAI to enhance and support their instruction.

Discussions

The fourth industrial revolution (4IR) has brought many changes in almost every sector of the economy, introducing and integrating technology into our daily activities. The education sector has experienced an expansion of instructional technology integration to aid teaching and learning (Swlwyn et al., 2020). As highlighted above, the evolution of digital learning for Industry 4.0 has brought many changes in how we teach, students learn, and assessment practices. Theoretical and technological perspectives have transformed the present and future of mathematics education. The current state of mathematics education demands a critical perspective on how the subject is taught and learned in schools.

In drawing attention to the progress made concerning the different interventions, we discussed the concept of CAI, which could be implemented in mathematics classrooms to enhance student's learning experiences and performance. Our presentation discussed CAI's important role in preparing critical thinkers who can use the knowledge acquired to solve real-life societal problems. As highlighted, we have critically analysed the features of CAI, instructional modes in CAI, and the design of CAI in mathematics education. Our discussions have thrown more light on the changing role of the teacher and the way mathematics is taught and learned in schools. The role of the teacher in a CAI classroom has also been evolving, and integrating technology in the teaching and learning of mathematics has become the new normal. A critical analysis of our meta-analysis studies presented above shows a consistent improvement in learner achievement, engagement, and motivation due to using CAI. It is, therefore, not surprising that researchers like Seo and Woo (2010) have advocated using a CAI to provide instructional content.

Notwithstanding the challenges associated with implementing CAI into teaching and learning mathematics, we believe that teachers can contribute to meaningful student learning in their classrooms with the appropriate integration and use of available instructional technological resources. We also explored different theoretical perspectives that influence mathematics teaching and learning and how these theories shape teachers' thinking, practices, and identity. We also critique some of the technology integration frameworks teachers draw on in using CAI. There is no little to claim that the overreliance on a teaching approach, or between the teacher-centred and student-centred approach, has become the order of the day, with many teachers still deciding which approach to choose at a particular time. Drawing on Luitel and Taylor's (2009) adversarial "metaphors of mathematics as a body of pure knowledge and mathematics as a cultural activity", the choice should not just be based on student-centred or teacher-centred. Learning affects the entire web of being, which goes beyond cognitive knowledge, hence the need for mathematics

education, which integrates multiple natures of mathematics that provide different learning opportunities, both deductive analytical and dialectical knowledge (Begg, 2002; Luitel & Taylor, 2009).

Implications for Further Research

The call for innovative ways of teaching and learning mathematics across all levels of education speaks to the struggles that most students face in learning mathematics, as reflected in students' performances in mathematics at the national and international levels. The call for innovative ways of teaching and learning the subject is not just a result of persistent underachievement of students in mathematics but also an indication of the struggles we face in our quest to achieve the Sustainable Development Goals (SDGs), especially SDG4, which aims at ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all. This meta-analysis and review of related literature further support the idea that there is a direct correlation between the use of technology in learning and students' achievement and learning experiences.

Chang et al. (2006) stated that using CAI could bring the needed change in mathematics classrooms where students are actively involved in the teaching-learning process and use different problem-solving strategies in developing a conceptual understanding of mathematical concepts. Similarly, as highlighted by Genlott and Grönlund (2016), despite the numerous precautions from many researchers about the fact that technology itself may not necessarily lead to improvement in students' results, it is worth noting that the integration of such technological tools in the teaching and learning of mathematics could reinforce pedagogical factors in the classroom to enhance learning and achievements.

Considering the complexity of integrating CAI in mathematics lessons, there is a need for professional development training for teachers and sensitization workshops for students on how this could be done so that both teachers and students could experience the benefits of CAI in mathematics classrooms. In addition, CAI curricula need to be developed with particular reference to how contextual factors could be used to harness the process of integrating context-specific CAI in mathematics lessons. This current study is limited to a review of relevant literature and meta-analysis; hence, empirical studies are needed to examine how CAI could be implemented in different mathematics classrooms. Based on SDG4, it will be good to see different research looking at implementing CAI in different countries and contexts to help provide a holistic picture of the phenomenon.

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References

- Abd-Kadir, J., & Hardman, F. (2007). The discourse of whole class teaching: A comparative study of Kenyan and Nigerian primary English lessons. *Language and Education*, 21(1), 1–15. <https://doi.org/10.2167/le684.0>
- Abelson, H., Goodman, N., & Rudolph, L. (1974). *LOGO Manual* (AIM-313). Artificial Intelligence Lab, Massachusetts Institute of Technology. <https://dspace.mit.edu/handle/1721.1/6226>
- Alessi, S. M., & Trollip, S. R. (1991). *Computer-based instruction: Methods and development* (2nd ed.). Pearson College Div.
- Asami-Johansson, Y., Attorps, I., & Winsløw, C. (2020). Comparing mathematics education lessons for primary school teachers: Case studies from Japan, Finland and Sweden. *International Journal of Mathematical Education in Science and Technology*, 51(5), 688–712. <https://doi.org/10.1080/0020739X.2019.1614688>
- Baker, R. S. J., D’Mello, D., Rodrigo, S. K., Ma, M. T., & Graesser, A. C. (2010). Better to be frustrated than bored: The incidence, persistence, and impact of learners’ cognitive–affective states during interactions with three different computer-based learning environments. *International Journal of Human-Computer Studies*, 68(4), 223–241. <https://doi.org/10.1016/j.ijhcs.2009.12.003>
- Balacheff, N., & Kaput, J. J. (1996). Computer-based learning environments in mathematics. In A. J. Bishop, K. Clements, C. Keitel, J. Kilpatrick, & C. Laborde (Eds.), *International handbook of mathematics education: Part 1* (pp. 469–501). Springer. https://doi.org/10.1007/978-94-009-1465-0_14
- Becker, H. J. (1992). Computer-based integrated learning systems in the elementary and middle grades: A critical review and synthesis of evaluation reports. *Journal of Educational Computing Research*, 8(1), 1–41. <https://doi.org/10.2190/23BC-ME1W-V37U-5TMJ>
- Begg, A. (2002). Enactivism and some implications for education: A personal perspective. *Vinculum*, 39(2), 4–12. <https://doi.org/10.3316/aeipt.121113>
- Cai, J., Lew, H. C., Morris, A., Moyer, J. C., Fong Ng, S., & Schmittau, J. (2005). The development of students’ algebraic thinking in earlier grades. *Zentralblatt Für Didaktik Der Mathematik*, 37(1), 5–15. <https://doi.org/10.1007/BF02655892>
- Chang, K. E., Sung, Y. T., & Lin, S. F. (2006). Computer-assisted learning for mathematical problem solving. *Computers & Education*, 46(2), 140–151. <https://doi.org/10.1016/j.compedu.2004.08.002>
- Chauhan, S. (2017). A meta-analysis of the impact of technology on learning effectiveness of elementary students. *Computers & Education*, 105, 14–30. <https://doi.org/10.1016/j.compedu.2016.11.005>
- Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, 9, 88–113. <https://doi.org/10.1016/j.edurev.2013.01.001>
- Chou, B. K. P. (2012). The paradox of educational quality and education policy in Hong Kong and Macau. *Chinese Education & Society*, 45(2), 96–110. <https://doi.org/10.2753/CED1061-1932450206>
- Christmann, E., Badgett, J., & Lucking, R. (1997). Progressive comparison of the effects of computer-assisted instruction on the academic achievement of secondary students. *Journal of Research on Computing in Education*, 29(4), 325–337. <https://doi.org/10.1080/08886504.1997.10782202>
- Corey, D. L., Peterson, B. E., Lewis, B. M., & Bukarau, J. (2010). Are there any places that students use their heads? Principles of high-quality Japanese mathematics instruction. *Journal for Research in Mathematics Education*, 41(5), 438–478.
- Croy, M. J. (1988). The use of CAI to enhance human interaction in the learning of deductive proof construction. *Computers and the Humanities*, 22(4), 277–284. <https://doi.org/10.1007/BF00118603>

- Cullen, C. J., Hertel, J. T., & Nickels, M. (2020). The roles of technology in mathematics education. *The Educational Forum*, 84(2), 166–178. <https://doi.org/10.1080/00131725.2020.1698683>
- De Witte, K., Haelermans, C., & Rogge, N. (2015). The effectiveness of a computer-assisted math learning program. *Journal of Computer Assisted Learning*, 31(4), 314–329. <https://doi.org/10.1111/jcal.12090>
- Dolasinski, M. J., & Reynolds, J. (2020). Microlearning: A new learning model. *Journal of Hospitality & Tourism Research*, 44(3), 551–561. <https://doi.org/10.1177/1096348020901579>
- Edutech202. (2012). Computer in education: Computer-assisted instruction. In *Introduction to educational communication and technology*. <http://edutech202.blogspot.com/2012/12/computer-in-education-computer-assisted.html>
- Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, 47(4), 47–61. <https://doi.org/10.1007/BF02299597>
- European Commission. (2000). *Communication from the Commission-e-Learning—Designing tomorrow's education* (pp. 1–13). COM (2000) 318 final.
- Fadda, D., Pellegrini, M., Vivanet, G., & Zandonella Callegher, C. (2022). Effects of digital games on student motivation in mathematics: A meta-analysis in K-12. *Journal of Computer Assisted Learning*, 38(1), 304–325. <https://doi.org/10.1111/jcal.12618>
- Fede, J. L., Pierce, M. E., Matthews, W. J., & Wells, C. S. (2013). The effects of a computer-assisted, schema-based instruction intervention on word problem-solving skills of low-performing fifth grade students. *Journal of Special Education Technology*, 28(1), 9–21. <https://doi.org/10.1177/016264341302800102>
- Fletcher-Flinn, C. M., & Gravatt, B. (1995). The efficacy of computer-assisted instruction (CAI): A meta-analysis. *Journal of Educational Computing Research*, 12(3), 219–241. <https://doi.org/10.2190/51D4-F6L3-JQHU-9M31>
- Forbringer, L., & Weber, W. (2014). *RtI in math: Evidence-based interventions for struggling students*. Routledge.
- Genlott, A. A., & Grönlund, Å. (2016). Closing the gaps—Improving literacy and mathematics by ict-enhanced collaboration. *Computers & Education*, 99, 68–80. <https://doi.org/10.1016/j.compedu.2016.04.004>
- Gersten, R., Beckmann, S., Clarke, B., Foegen, A., Marsh, L., Star, J. R., & Witzel, B. (2009). Assisting students struggling with mathematics: response to intervention (rti) for elementary and middle schools. IES practice guide. NCEE 2009–4060. In *What works Clearinghouse*. What Works Clearinghouse. <https://eric.ed.gov/?id=ED504995>
- Gränlund, R., Berglund, E., & Eriksson, H. (2000). Designing web-based simulation for learning. *Future Generation Computer Systems*, 17(2), 171–185. [https://doi.org/10.1016/S0167-739X\(99\)00112-0](https://doi.org/10.1016/S0167-739X(99)00112-0)
- 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>
- Hemmi, K., Lepik, M., & Viholainen, A. (2013). Analyzing proof-related competences in Estonian, Finnish and Swedish mathematics curricula—Towards a framework of developmental proof. *Journal of Curriculum Studies*, 45(3), 354–378. <https://doi.org/10.1080/00220272.2012.754055>
- Hemmi, K., Bråting, K., & Lepik, M. (2021). Curricular approaches to algebra in Estonia, Finland and Sweden—A comparative study. *Mathematical Thinking and Learning*, 23(1), 49–71. <https://doi.org/10.1080/10986065.2020.1740857>
- Henrekson, M., & Järvell, S. (2016). *Educational performance in Swedish schools is plummeting—What are the facts?* (pp. 1–49). The Royal Swedish Academy of Engineering Sciences (IVA).
- Hughes, J., Thomas, R., & Scharber, C. (2006). *Assessing technology integration: The rat—Replacement, amplification, and transformation—Framework* (pp. 1616–1620). <https://www.learntechlib.org/primary/p/22293/>

- Jones, K. (2000). The student experience of mathematical proof at university level. *International Journal of Mathematical Education in Science and Technology*, 31(1), 53–60. <https://doi.org/10.1080/002073900287381>
- Kulik, C.-L. C., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior*, 7(1), 75–94. [https://doi.org/10.1016/0747-5632\(91\)90030-5](https://doi.org/10.1016/0747-5632(91)90030-5)
- Kulik, J. A., Kulik, C.-L. C., & Bangert-Drowns, R. L. (1985). Effectiveness of computer-based education in elementary schools. *Computers in Human Behavior*, 1(1), 59–74. [https://doi.org/10.1016/0747-5632\(85\)90007-X](https://doi.org/10.1016/0747-5632(85)90007-X)
- Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, 22(3), 215–243. <https://doi.org/10.1007/s10648-010-9125-8>
- Liao, Y. C. (1998). Effects of hypermedia versus traditional instruction on students' achievement. *Journal of Research on Computing in Education*, 30(4), 341–359. <https://doi.org/10.1080/08886504.1998.10782232>
- Liao, Y. C. (2007). Effects of computer-assisted instruction on students' achievement in Taiwan: A meta-analysis. *Computers & Education*, 48(2), 216–233. <https://doi.org/10.1016/j.compedu.2004.12.005>
- Lindvall, J., Helenius, O., & Wiberg, M. (2018). Critical features of professional development programs: Comparing content focus and impact of two large-scale programs. *Teaching and Teacher Education*, 70, 121–131. <https://doi.org/10.1016/j.tate.2017.11.013>
- Lotz-Sisitka, H., Wals, A. E., Kronlid, D., & McGarry, D. (2015). Transformative, transgressive social learning: Rethinking higher education pedagogy in times of systemic global dysfunction. *Current Opinion in Environmental Sustainability*, 16, 73–80. <https://doi.org/10.1016/j.cosust.2015.07.018>
- Luitel, B. C., & Taylor, P. C. (2009). Defrosting and re-frosting the ideology of pure mathematics: An infusion of eastern-western perspectives on conceptualizing a socially just mathematics education. *Philosophy of Mathematics Education Journal*, 21, 1–25.
- Madej, L. (2022). Primary school students' knowledge of the equal sign—The Swedish case. *International Journal of Science and Mathematics Education*, 20(2), 321–343. <https://doi.org/10.1007/s10763-020-10144-z>
- Merrill, D. C., Reiser, B. J., Ranney, M., & Trafton, J. G. (1992). Effective tutoring techniques: A comparison of human tutors and intelligent tutoring systems. *Journal of the Learning Sciences*, 2(3), 277–305. https://doi.org/10.1207/s15327809jls0203_2
- Munter, C. (2014). Developing visions of high-quality mathematics instruction. *Journal for Research in Mathematics Education*, 45(5), 584–635. <https://doi.org/10.5951/jresmetheduc.45.5.0584>
- Niess, M. L. (2008). Guiding preservice teachers in developing TPCK. In *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 223–250). Routledge.
- Niess, M., Browning, C., Driskell, S., Johnston, C., & Harrington, R. (2009). *Mathematics teacher TPCK standards and revising teacher preparation* (pp. 3588–3601). <https://www.learntechlib.org/primary/p/31207/>
- Okolo, C. M. (1992). The effect of computer-assisted instruction format and initial attitude on the arithmetic facts proficiency and continuing motivation of students with learning disabilities. *Exceptionality*, 3(4), 195–211. <https://doi.org/10.1080/09362839209524815>
- Psycharis, S., & Kallia, M. (2017). The effects of computer programming on high school students' reasoning skills and mathematical self-efficacy and problem-solving. *Instructional Science*, 45(5), 583–602. <https://doi.org/10.1007/s11251-017-9421-5>
- Rakes, C. R., Valentine, J. C., McGatha, M. B., & Ronau, R. N. (2010). Methods of instructional improvement in algebra: A systematic review and meta-analysis. *Review of Educational Research*, 80(3), 372–400. <https://doi.org/10.3102/0034654310374880>
- Rakes, C. R., Stites, M. L., Ronau, R. N., Bush, S. B., Fisher, M. H., Safi, F., Desai, S., Schmidt, A., Andreasen, J. B., Saderholm, J., Amick, L., Mohr-Schroeder, M. J., & Viera, J. (2022). Teaching mathematics with technology: Tpack and effective teaching practices. *Education Sciences*, 12(2), 133. <https://doi.org/10.3390/educsci12020133>

- Ran, H., Kasli, M., & Secada, W. G. (2021). A meta-analysis on computer technology intervention effects on mathematics achievement for low-performing students in k-12 classrooms. *Journal of Educational Computing Research*, 59(1), 119–153. <https://doi.org/10.1177/0735633120952063>
- Renshaw, C. E., Taylor, H. A., & Reynolds, C. H. (1998). Impact of computer-assisted instruction in hydrogeology on critical-thinking skills. *Journal of Geoscience Education*, 46(3), 274–279. <https://doi.org/10.5408/1089-9995-46.3.274>
- Rosen, Y., & Salomon, G. (2007). The differential learning achievements of constructivist technology-intensive learning environments as compared with traditional ones: A meta-analysis. *Journal of Educational Computing Research*, 36(1), 1–14. <https://doi.org/10.2190/R8M4-7762-282U-554J>
- Rosenquist, B. A., Henrick, E. C., & Smith, T. M. (2015). Research–practice partnerships to support the development of high-quality mathematics instruction for all students. *Journal of Education for Students Placed at Risk (JESPAR)*, 20(1–2), 42–57. <https://doi.org/10.1080/010824669.2014.988335>
- Rushby, N. J. (2019). *An introduction to educational computing*. Routledge.
- Sampath, K., Panneerselvam, A., & Santhanam, S. (1990). *Introduction to educational technology*. Sterling Publishers.
- Schwier, R., & Misanchuk, E. R. (1993). *Interactive multimedia instruction*. Educational Technology Publications.
- Selwyn, N., Pangrazio, L., Nemorin, S., & Perrotta, C. (2020). What might the school of 2030 be like? An exercise in social science fiction. *Learning, Media and Technology*, 45(1), 90–106. <https://doi.org/10.1080/17439884.2020.1694944>
- Seo, Y.-J., & Woo, H. (2010). The identification, implementation, and evaluation of critical user interface design features of computer-assisted instruction programs in mathematics for students with learning disabilities. *Computers & Education*, 55(1), 363–377. <https://doi.org/10.1016/j.compedu.2010.02.002>
- Sharma, R. (2017). Computer assisted learning—A study. *International Journal of Advanced Research*, 4(2), 102–105.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.
- Skinner, B. F. (1958). Teaching machines: From the experimental study of learning come devices which arrange optimal conditions for self-instruction. *Science*, 128(3330), 969–977. <https://doi.org/10.1126/science.128.3330.969>
- Slavin, R. E., & Lake, C. (2008). Effective programs in elementary mathematics: A best-evidence synthesis. *Review of Educational Research*, 78(3), 427–515. <https://doi.org/10.3102/0034654308317473>
- Soe, K., Koki, S., & Chang, J. M. (2000). *Effect of computer-assisted instruction (CAI) on reading achievement: A meta-analysis* (p. 26). Pacific Resources for Education and Learning. <https://eric.ed.gov/?id=ED443079>
- Spittlgerber, F. L. (1979). Computer-based instruction: A revolution in the making? *Educational Technology*, 19(1), 20–26.
- Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, 94, 252–275. <https://doi.org/10.1016/j.compedu.2015.11.008>
- Tokac, U., Novak, E., & Thompson, C. G. (2019). Effects of game-based learning on students' mathematics achievement: A meta-analysis. *Journal of Computer Assisted Learning*, 35(3), 407–420. <https://doi.org/10.1111/jcal.12347>
- Tucker, S. I. (2018). Applying the modification of attributes, affordances, abilities, and distance for learning framework to a child's multi-touch interactions with an idealized number line. In L. Ball, P. Drijvers, S. Ladel, H.-S. Siller, M. Tabach, & C. Vale (Eds.), *Uses of technology in primary and secondary mathematics education: Tools, topics and trends* (pp. 35–57). Springer. https://doi.org/10.1007/978-3-319-76575-4_3

- UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO. <https://doi.org/10.54675/CGBA9153>
- Usiskin, Z. (1995). Why is algebra important to learn? *American Educator*, 19(1), 30–37.
- Van Scoyoc, A. M. (2003). Reducing library anxiety in first-year students: The impact of computer-assisted instruction and bibliographic instruction. *Reference & User Services Quarterly*, 42(4), 329–341.
- Xie, C., Cheung, A. C. K., Lau, W. W. F., & Slavin, R. E. (2020). The effects of computer-assisted instruction on mathematics achievement in mainland China: A meta-analysis. *International Journal of Educational Research*, 102, 101565. <https://doi.org/10.1016/j.ijer.2020.101565>
- Zeng, J., Parks, S., & Shang, J. (2020). To learn scientifically, effectively, and enjoyably: A review of educational games. *Human Behavior and Emerging Technologies*, 2(2), 186–195. <https://doi.org/10.1002/hbe2.188>
- Zheng, B., Warschauer, M., Lin, C.-H., & Chang, C. (2016). Learning in one-to-one laptop environments: A meta-analysis and research synthesis. *Review of Educational Research*, 86(4), 1052–1084. <https://doi.org/10.3102/0034654316628645>

Chapter 3

Exploring the Use of ChatGPT as a Tool for Developing Eportfolios in ESL Classrooms



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Introduction

In an era marked by rapid technological advancements, integrating artificial intelligence (AI) systems has permeated various facets of our lives, including education. The emergence of AI language models, such as ChatGPT, has opened up new possibilities for personalized learning and instructional support. This chapter delves into using ChatGPT in eportfolio development, exploring its potential benefits, challenges, and ethical considerations.

The chapter begins by highlighting the importance of eportfolios as a tool for showcasing and reflecting on individual learning journeys. It emphasizes the need for personalization in educational settings and discusses how technology brilliant learning systems have made personalized learning more attainable. However, it also underscores that technology alone cannot create a truly customized learning environment, emphasizing the significance of student characteristics, social interaction, guidance, and institutional support.

One of the challenges associated with integrating AI language models like ChatGPT is the potential overreliance on AI-generated content, which can diminish

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critical thinking skills and undervalue human-generated content. The chapter explores the balance that needs to be struck in leveraging ChatGPT for eportfolio development while nurturing essential cognitive faculties and independent learning capabilities.

Ethical considerations form another crucial aspect of the discussion. The potential for biases in AI-generated content, the privacy and security of personal data, and the ethical implications of emotional manipulation and persuasion through AI systems are examined. Moreover, the chapter delves into concerns regarding the quality of feedback provided by ChatGPT and the risk of potential plagiarism arising from the lack of explicit sources or citations. Furthermore, the technical accessibility of ChatGPT is addressed, emphasizing the need for students to develop digital competence and responsible usage of AI-driven tools. The chapter also touches upon the global landscape, where certain countries have enacted regulations or criminalized the use of ChatGPT, highlighting the complex interplay between accessibility, political influence, and privacy protection.

By exploring the potential benefits, challenges, and ethical considerations of incorporating ChatGPT in eportfolio development, this chapter aims to provide educators, researchers, and policymakers with a comprehensive understanding of the implications and complexities of integrating AI language models in educational contexts. Through critically examining these issues, stakeholders can navigate the path forward with a balanced approach, harnessing the potential of AI while upholding the principles of quality education and ethical practices.

Overall, this chapter sheds light on the multifaceted dimensions of leveraging ChatGPT in eportfolio development, offering insights and guidance for those interested in exploring the intersection of AI and education.

Literature Review

Eportfolios in Language Learning

Before delving into a detailed discussion about the concept of an eportfolio, it is crucial first to understand the earlier idea of the portfolio, which served as the foundation for the development of the eportfolio. The portfolio concept has been extensively researched and discussed across various disciplines (Slepcevic-Zach & Stock, 2018), resulting in diverse perspectives and applications documented in the literature. In the realm of education, one of the earliest and widely referenced definitions was put forth by Paulson et al. (1991):

A portfolio is a purposeful collection of student work that exhibits the student's efforts, progress, and achievements in one or more areas. The group must include student participation in selecting contents, the criteria for selection, the criteria for judging merit, and evidence of student self-reflection. (p. 60).

Later discussions in educational fields have also seen the emergence of other definitions (e.g. Baris & Tosun, 2011; Barret, 2004; Chang, 2008). Despite the various interpretations of the concept, three fundamental elements endure from Paulson and colleagues' original definition. Firstly, a portfolio must consist of a purposefully curated collection of learning artefacts rather than a random assortment of works. Secondly, this compilation of work should facilitate the representation of student's competencies over time, aligning with the learning process rather than merely reflecting its outcomes. Finally, students' autonomy holds significance in developing portfolios as they are responsible for selecting and evaluating their work.

With the advent of transformative educational technologies, the traditional paper-based portfolio has evolved into its computer-based counterpart, an eportfolio. This digital portfolio, also called a digital or electronic portfolio (Barret, 2004), has yet to achieve consensus among scholars and institutions regarding its definition. This lack of agreement primarily stems from varied purposes of utilizing eportfolios in education. A broad definition of *eportfolio* was proposed by Jenson and Treuer (2014), seeing eportfolio as "a tool for documenting and managing one's learning over a lifetime in ways that foster deep and continuous learning" (p. 55). In this sense, eportfolios transcend formal education, emphasizing lifelong learning as a fundamental attribute for learners. However, this definition needs to be revised to elucidate the role of technology in developing eportfolios compared to traditional portfolios. Other researchers (e.g. Al-Naibi et al., 2018; Meyer et al., 2010) differentiate eportfolios from traditional portfolios by integrating technology in collecting, presenting, and evaluating students' work. In particular, students' work can be shown in various multimedia formats, such as texts, audio recordings, videos, and graphics. These technological advancements are believed to enhance portfolio development and assessment, mainly through archiving, linking and thinking, storytelling, collaborating, and publishing (Barrett, 2007).

The rationales behind the adoption of eportfolio indeed vary, and depending on the purposes, the content of the eportfolio is determined. In this chapter, focusing on the application of eportfolio in ESL classrooms, the discussion shall be narrowed down to two primary purposes: documenting the learning process and assessing activities (Barrett, 2007). Recent studies demonstrate that eportfolios are an effective tool that supports learning while providing an alternative to standardized tests. Eportfolios are crucial in self-assessment, peer assessment, and feedback sharing. Students are encouraged to reflect on their work during the eportfolio development process and engage with feedback from peers and teachers (Stefani et al., 2007). The collaborative features of eportfolios facilitate peer assessment, allowing students to actively discuss and evaluate each other's work. Students can cultivate self-directed learning skills through these processes by improving self-reflection and reviewing educational outcomes (Slepcevic-Zach & Stock, 2018). Students may also be able to select the best among their works to showcase in a presentation eportfolio (Barrot, 2019). Teachers can later utilize this showcase to obtain authentic evidence of students' competencies and evaluate it against predetermined criteria. In summary, eportfolios are a valuable tool for teachers and learners, providing proof of the learning process and facilitating assessment.

Key Components of Eportfolios

The components of eportfolios vary depending on their intended purpose. Potential contents of eportfolios are diverse and may encompass various elements, including but not limited to factual information, reflections, artefacts of learning, supporting evidence for considerations or claims, records of group discussions or Q&A sessions, observations, feedback, and annotation (Walland & Shaw, 2022). These elements can be flexibly selected and presented in multiple forms of digitally stored media, highlighting the versatility of eportfolios.

Artefacts of learning play a crucial role in the development of eportfolios. The process begins by defining the purpose of the eportfolio, identifying the target audience, such as students, parents, teachers, or employers, and determining the available sources of evidence or learning artefacts (Barrett, 2000). The selection of these artefacts should be based on the requirements of the eportfolio assessment and the predetermined learning outcomes. After deciding on the artefacts to include, learners should utilize the features of the eportfolio platforms appropriately to synthesize their learning materials and showcase multimedia content effectively.

Reflection is another essential component of eportfolios as a tool for evaluating the learning process. It encompasses evaluation, self-assessment, and the establishment of future learning goals based on current outcomes and the assessment of learning achievements (Barrett, 2000). The reflective feature of eportfolios empowers students to thoroughly analyse their learning journey and make necessary adjustments to their behaviours in subsequent learning experiences (Jenson & Treuer, 2014).

In addition, feedback in eportfolios serves as a channel for storing and providing comments on learning products, aligning them with the initial goals set for building the eportfolio and considering the learner's self-assessment (Barrett, 2000). Portfolios effectively facilitate feedback between learners and allow learners to yield more benefits from the given input in many studies (Barrot, 2023). As such, educators must develop strategies to encourage constructive feedback for the learners.

Publishing and collaborating elements in eportfolios offer several advantages compared to traditional portfolios. These electronic features include storage, linking, collaboration, comprehensive representation of the work process, and publication on electronic systems (Barrett, 2007). The ability to link and organize multimedia information is also noteworthy. With this functionality, learning products can be presented in a more organized and purposeful manner, ensuring clarity and systematicity, as mentioned above.

The Benefits for Language Learners

Eportfolios and Language Skills Development

Many scholars have researched the effects of eportfolios in ESL classrooms, mainly focusing on students' writing performance. Eportfolios assist students in improving writing accuracy by utilizing editing, spelling, and grammar-checking features available on the eportfolio platform (Meshkat & Goli, 2012). Integrating multimedia elements in eportfolios enables students to gather topic-related information and enhance the effectiveness of their writing presentations (Thang et al., 2012). Keeping an e-portfolio also helps cultivate a habit of writing regularly in learners and fosters their motivation during learning (Le et al., 2023). Furthermore, constructing eportfolios on social media platforms requires students to consider their audience, leading to increased awareness, reflection, and sensitivity towards the needs and interests of their intended readers during the drafting process (Barrot, 2020). Through recursive activities such as reviewing, editing, and reflecting, eportfolios contribute to better performance in writing tests, particularly regarding vocabulary knowledge, while reducing anxiety and enhancing motivation among upper-secondary school students (Le et al., 2023).

Although receiving comparatively less attention, using eportfolios in ESL speaking classes has enhanced students' oral performance. Eportfolios can improve students' verbal communication abilities, specifically regarding total word count and lexical complexity (Huang & Hung, 2010). In flipped classrooms, students who received instruction through eportfolios demonstrated superior speaking performance than those in traditional instructional settings (Kusuma et al., 2021).

In contrast, the application of eportfolios in reading and listening courses has received relatively less research attention. Nevertheless, some scholars have highlighted the potential of eportfolios in developing these two language skills. A theoretical review by Li et al. (2013) suggests that implementing e-portfolios in English listening courses for English majors encourages active participation and motivates students to engage in autonomous listening activities outside of class. Furthermore, web-based eportfolios have positively impacted reading proficiency during out-of-class language learning practices (Fathali & Okada, 2016).

Eportfolios, Autonomy, and Engagement

Eportfolio is also gaining in popularity due to the ability to improve students' autonomy and engagement in their learning process. As Baturay and Daloğlu (2010) point out, eportfolios can facilitate self-reflection, allowing students to revisit their strengths and weaknesses better than the traditional test scores. By implementing eportfolios, students can evaluate their writing and monitor their progress throughout their courses, demonstrating high responsibility for their learning (Purwanti, 2015). Eportfolios also foster students' sense of ownership, diversify their learning

experiences, and heighten their awareness of the learning process (Ivanova, 2017). Students learning with eportfolios in writing courses can better track their achievements and are more involved in learning (Barrot, 2020). Introducing eportfolios in flipped classrooms leads to varied learner engagements across learning behavioural, cognitive, and affective aspects (Kusuma et al., 2021).

With the assistance of technology, eportfolios provide students with enhanced communication, collaboration, and knowledge exchange opportunities with their peers and instructors. Eportfolios provide valuable feedback from instructors and peers, offering students practical insights into their current level and future learning plans (Le et al., 2023; Ivanova, 2017). Keeping an e-portfolio also eliminated their discomfort and insecurity in communicating with peers and instructors (Baturay & Daloğlu, 2010). The additions of the Internet and electronic devices have also made eportfolios more helpful, making the knowledge exchange process less complicated and more efficient (Chang, 2008).

Challenges in Eportfolio Development

The discussion regarding eportfolios and their benefits is often accompanied by concerns related to the development process. These challenges are essential to consider not only for teachers but also for students and administrators. One common concern is the portfolio platforms' user-friendliness (EUFolio, 2015). Students also report that their digital literacy is an obstacle when constructing their eportfolios (Uí Choistealbha, 2018). From a teacher's perspective, the lack of technical skills among educators when utilizing eportfolios in the teaching process is also a barrier. Teachers believe their knowledge and technology experience are crucial in developing e-portfolio platforms and providing technical support to students throughout the teaching and learning process (Yastibas & Cepik, 2015). Poor Internet connections and the reliability of eportfolio platforms have also been identified as challenges that students have to face (Barrot, 2016).

As eportfolios differ from traditional paper-based portfolios primarily through their use of technology, interoperability of systems becomes a significant issue. Administrators pay close attention to this issue when considering the implementation of eportfolios using existing learning management systems (Cheng, 2008). Platforms that need to support multimedia integration (e.g. Google Sites) adequately may also cause hindrances to the learning process with eportfolios (Suparjan & Mariyadi, 2021). The interactive capabilities of the platforms should be carefully considered to maximize the potential of eportfolios in collaboration, feedback, and reflection. Otherwise, eportfolios may not foster learning or confuse teachers and students.

The amount of time and workload generated by eportfolios is another significant concern for teachers and students. Cheng (2008) observes that teachers are worried about the increasingly heavy workload they must bear when implementing eportfolio in classrooms. Such a problem was attributed to the integration of online assessment, which may entail several issues, including plagiarism among students (Cheng,

2008; Kabilan & Khan, 2012). From the students' voices, building eportfolio is demanding in terms of time and effort (Alanazi & Bensalem, 2022). When students have yet to gain experience with eportfolio development, this process requires more effort from students and teachers to get familiar with the tool (Le et al., 2023).

When building eportfolio in online environments, data security is another issue. Both administrators and students raise concerns about Internet privacy and data security in portfolio-supported courses (Cheng, 2008). When using social media-based eportfolio (such as Facebook), privacy issues may prevent eportfolio from eliminating students' anxiety during the writing process (Barrot, 2016). Students feel insecure when posting their work online as a part of their portfolio due to the fear of being judged by the audience. When using social media sites to develop eportfolio, it is also essential to consider the risk of cyber attacks on these platforms (Rojas-Kramer et al., 2015).

ChatGPT and Artificial Intelligence in Education

ChatGPT is an AI chatbot developed by OpenAI, released in November 2022. It combines chatbot functionality with a generative pre-trained transformer (GPT), a large language model. Large language models (LLMs) are artificial intelligence models designed to understand, interpret, and generate human-like text based on vast input data. By training on billions of sentences from diverse sources – such as websites, customer data, past reports, and more – LLM acquires a comprehensive knowledge of data analysis and context, allowing them to excel in natural language processing tasks. ChatGPT is a significant language model that uses generative AI, built upon OpenAI's GPT models, specifically GPT-3.5 and GPT-4 and has been fine-tuned for conversational applications (OpenAI, n.d.). ChatGPT undergoes pre-training using a substantial collection of text data from various sources, such as books, articles, and websites (Abdullah et al., 2022). ChatGPT gains knowledge of the connections and structures within natural language through language modelling tasks. As a result, it becomes proficient at producing logical and authentic responses during conversations.

Features and Capabilities of ChatGPT

ChatGPT has revolutionized the field of natural language processing with its remarkable features, including its ability to comprehend and generate texts, fine-tuning capabilities, and aptitude for zero-shot and few-shot learning. These notable features of ChatGPT have positioned it at the forefront of conversational AI.

An outstanding characteristic of ChatGPT is its capacity to understand and produce texts in specific contexts, leading to interactions with users that are more authentic and engaging (Javaid et al., 2023; Ray, 2023). By combining its contextual understanding with a wide-ranging knowledge base gathered from diverse domains

and sources, ChatGPT can generate responses tailored to specific contexts, serving various purposes and environments accurately and appropriately (Barrot, 2023). In addition, ChatGPT has the capacity to create responses in multiple styles and languages (Deng & Lin, 2023; Javaid et al., 2023).

The fine-tuning feature of ChatGPT enables developers to tailor the model to specific tasks or domains, including but not limited to customer support, content creation, tutoring, and translation (Ray, 2023). Furthermore, through the fine-tuning process, ChatGPT acquires the ability to retain past conversations, rectify errors, and reject inappropriate requests (Barrot, 2023).

ChatGPT's zero-shot and few-shot learning capabilities are remarkable advancements in conversational AI. ChatGPT can create replies for tasks it has never encountered before in zero-shot learning, and it can also learn new lessons with only a few instances in few-shot education (Ray, 2023). Responses can be enhanced by presenting supplementary examples before posing further inquiries (Zhu et al., 2023). This ability of ChatGPT to rapidly adapt and expand its capabilities without extensive training is a significant advantage.

Large Language Models and AI-Powered Tools in Educational Settings

The integration of large language models and AI-powered tools has opened up new possibilities in the field of education. To start with, Abdelghani et al. (2022) have found that using natural language prompts and large language models can help students develop their ability to ask thought-provoking questions. In addition, AI chatbots have also emerged as a promising tool for enhancing linguistic output gains and reducing anxieties in language learning learners. Conversationally enhanced AI chatbots may help leverage concerns and learning inhibitions, particularly for those teaching English as a foreign language (Bao, 2019). In the context of creative writing, the utilization of AI-powered pedagogical tools, such as the Poetry Machine, has shown desirable effects through giving inspiration for poem writing and support during the writing process to lower secondary students (Kangasharju et al., 2022) the assessment process, automatic quiz generation powered by AI has also displayed its potential value (Dijkstra et al., 2022). This could further complement traditional assessment in our effort to enhance the learning experience.

ChatGPT has been gaining popularity since its introduction and applied variedly in education. In medical education, the potential assistance of ChatGPT has been demonstrated in a study examining its performance in the United States Medical Licensing Exam (USMLE) (Kung et al., 2023). ChatGPT's performance was impressive on all three exam components without any specialized training or reinforcement, and it provided many valuable insights in its explanations. Students in journalism and media education can also benefit from using input text prompts in ChatGPT, which then rapidly generates text responses by leveraging its knowledge acquired through machine learning during interactions with the Internet (Pavlik, 2023). ChatGPT has also been applied in programming courses by generating programming exercises, with most automatically generated content being original,

logical, and sometimes even immediately usable (Sarsa et al., 2022). It may also enable instructors to enhance the personalized learning experience for students by analysing their preferences, strengths, and areas for improvement (Baidoo-Anu & Owusu Ansah, 2023).

Integrating ChatGPT into the e-Portfolio Development Process

In an era marked by technological advancements and a growing emphasis on digital portfolios, integrating ChatGPT into the e-portfolio development process has emerged as a transformative practice. This section discusses the utilization of this AI-powered chatbot to bring forth many benefits for students and educators alike. When skilfully facilitated and fine-tuned by teachers, the integration of ChatGPT into the e-portfolio development process enhances students' learning experiences, promotes their growth and success, and creates a positive and conducive atmosphere for e-portfolio development.

A Simple and User-Friendly e-Portfolio Platform

ChatGPT, with its chatbot interface, emerges as a unique and user-friendly e-portfolio platform, catering to the needs of students in a manner that minimizes frustration and enhances their overall experience. By adopting a conversational approach, ChatGPT offers a friendly and intuitive user interface, empowering students to navigate the e-portfolio development process quickly and confidently. One of the critical advantages of ChatGPT as a user-friendly e-portfolio platform is its natural and conversational interaction. Students can engage with ChatGPT, like chatting with real people (Abdullah et al., 2022). This chatbot interface eliminates the complexities often associated with traditional e-portfolio platforms, where students may need help finding the right buttons or menus (Nguï et al., 2022). With ChatGPT, the user interface is simplified, reducing the cognitive load and enabling students to focus on the content and purpose of their e-portfolio.

Furthermore, ChatGPT's conversational interface is a user-friendly feature that allows students to ask questions, seek guidance, and receive prompt responses (Tlili et al., 2023). Instead of navigating through complex menus or searching for help resources, students can type their queries or concerns, and ChatGPT will provide relevant and tailored assistance. This intuitive interaction helps students feel supported throughout the learning process, enhancing their confidence and reducing frustration (Tlili et al., 2023).

ChatGPT's user-friendly interface is characterized by its adaptability and personalized approach (Iskender, 2023). As students engage in conversations with ChatGPT, the platform learns from their interactions and adapts to their individual needs and preferences. Over time, ChatGPT becomes more familiar with each student's writing style, goals, and challenges, allowing for a tailored and personalized

experience. This adaptability fosters a sense of ownership and connection with the platform, making it a trusted companion in the e-portfolio development journey.

Another aspect contributing to ChatGPT's user-friendly nature is its ability to provide real-time feedback and suggestions (Iskender, 2023). As students draft their e-portfolio entries, ChatGPT can analyse their writing, offer grammar and spelling suggestions, and provide feedback on their content's clarity and coherence. This instant feedback mechanism enhances the quality of students' e-portfolio entries and instils a sense of continuous improvement and growth mindset (Ershova et al., 2021).

Reducing the Time and Workload with Automated Tasks

Integrating ChatGPT in the e-portfolio development process offers a range of advantages, one of which is its ability to automate tasks and alleviate the time and workload typically associated with e-portfolio development. By leveraging the capabilities of ChatGPT, teachers can streamline the assessment process and focus on providing valuable feedback and engaging with students (Bernius et al., 2022). ChatGPT's ability to automate data analysis can contribute to more insightful and data-driven assessments. It can analyse the data collected from e-portfolios, extracting valuable insights and trends to inform teachers' evaluation and feedback (Badini et al., 2023). By providing teachers with a comprehensive overview of student's progress, strengths, and areas for improvement, ChatGPT empowers them to deliver targeted and individualized feedback (Iskender, 2023). This automation of data analysis saves time and enhances the quality and depth of assessment, resulting in more meaningful input and support for students' learning journeys (Bauer et al., 2023). Teachers can focus on reviewing and evaluating the content, reflections, and artefacts within e-portfolios, providing constructive feedback that supports students' growth and development. With reduced administrative burden, teachers can engage in more in-depth discussions, address students' questions and concerns, and foster a supportive and interactive e-portfolio assessment environment.

Fostering Students' Autonomy in e-Portfolios

With its prompt responses and valuable insights, ChatGPT is a reliable companion for students, helping them overcome obstacles and progress more efficiently. When students encounter challenges or have questions regarding their e-portfolio development, ChatGPT can provide immediate responses, eliminating the need to wait for teacher availability or rely solely on self-directed research (Tlili et al., 2023). This instant support ensures that students can address their concerns promptly, enabling them to move forward with their e-portfolio development without unnecessary delays.

Students can seek guidance from ChatGPT on various aspects of e-portfolio development. They can receive advice on selecting appropriate artefacts

demonstrating their learning achievements and growth. ChatGPT can offer suggestions for reflecting on their learning experiences in a meaningful and insightful manner (Tlili et al., 2023). It can guide organizing and presenting e-portfolios, optimizing the layout, multimedia integration, and overall cohesiveness. With access to such guidance, students can navigate the e-portfolio development process more effectively, saving time and effort that might otherwise be spent on trial and error.

Moreover, ChatGPT's ability to provide prompt responses contributes to the overall efficiency of the e-portfolio development process. Students no longer need to wait for teacher feedback or schedule meetings for clarification (Badini et al., 2023). With ChatGPT readily available, they can seek answers to their questions and receive immediate support, allowing them to progress more smoothly and effectively (Cotton et al., 2023). This efficiency reduces the perceived demands on students' time and effort, making the e-portfolio development process more manageable and less overwhelming.

Moreover, ChatGPT, as a user-friendly e-portfolio platform, is designed to provide seamless assistance. From the initial stages of setting goals and selecting artefacts to the final stages of reflecting on the learning journey, ChatGPT offers guidance and prompts to ensure students stay on track and make the most of their e-portfolio experience. The platform provides suggestions, asks probing questions, and encourages critical thinking, facilitating students' self-reflection and fostering a deeper understanding of their learning achievements (Bauer et al., 2023). ChatGPT's guidance and support extend beyond the technical aspects of e-portfolio development. It can also assist students in refining their reflections, encouraging more profound and meaningful self-assessment (Bernius et al., 2022). Conversations with ChatGPT allow students to gain insights into their learning journeys and enhance their self-awareness. They can receive suggestions on how to set and revise their learning goals based on their reflections and assessments of their achievements. This support helps students develop a sense of ownership and agency over their e-portfolio development, empowering them to take an active role in their learning and growth.

Empowering Students in a Dedicated and Controlled Environment

Integrating ChatGPT into the e-portfolio development process provides a dedicated and controlled environment that empowers students to develop their e-portfolios. In contrast to social media-based platforms that often give rise to privacy concerns and anxiety among students (Barrot, 2016, 2021), ChatGPT offers a secure space where students can confidently share their work without the fear of being subjected to judgement or potential privacy breaches (Abdullah et al., 2022). This secure and controlled environment provided by ChatGPT ensures that students' e-portfolios remain safeguarded and offers them peace and reassurance throughout the development process. They can curate and choose how to present their work, knowing their creations are shielded from unwarranted exposure. This controlled environment alleviates the apprehension that may arise when students consider sharing their

work publicly, mainly when they fear being evaluated or criticized by others (Cheng, 2008). With ChatGPT, students can focus on their creative expression, reflect on their learning journey, and showcase their achievements without the anxiety associated with public exposure.

Moreover, the dedicated and controlled nature of ChatGPT fosters a supportive learning environment (Tili et al., 2023). Students can engage in constructive conversations with the chatbot interface, seeking guidance and feedback to enhance their e-portfolios. The absence of external distractions and potentially negative influences ensures that students can concentrate solely on their growth and development, channelling their efforts into refining their best work. This controlled environment encourages students to take risks, explore new ideas, and push the boundaries of their creativity without the fear of external judgement.

The secure space provided by ChatGPT also nurtures students' confidence and self-esteem (Crawford et al., 2023). Knowing that their e-portfolios are shielded within a controlled environment, students can express themselves authentically, experimenting with different styles, formats, and content choices. This freedom to be themselves without the fear of judgement or comparison allows students to develop a sense of pride in their work. It fosters a positive mindset towards their learning journey. As students gain confidence in their abilities and witness their progress, their motivation and enthusiasm for e-portfolio development are bolstered.

Additionally, the controlled environment of ChatGPT promotes a sense of ownership and responsibility among students. By having sole control over their e-portfolios, students become more invested in their work and take greater accountability for its quality and development. They understand that their e-portfolios reflect their learning and growth, and this awareness drives them to produce work of higher calibre. The controlled environment encourages students to be proactive, taking the lead in their e-portfolio development and assuming responsibility for the outcomes.

Developing Students' Responsible Online Behaviours and Digital Citizenship

Using its vast knowledge and interactive capabilities, teachers can prompt ChatGPT to serve as a guiding force, providing students with essential guidance on ethical practices, copyright awareness, and the appropriate use of online resources throughout their e-portfolio journey. By instilling a sense of digital responsibility, students are empowered to make informed decisions regarding the content they include in their works, ensuring that they respect intellectual property rights and uphold ethical standards (Mhlanga, 2023).

ChatGPT can be crucial in raising students' awareness of ethical considerations when incorporating external content into e-portfolios. Through prompt and relevant responses, ChatGPT can educate students about the importance of citing sources, giving credit to original creators, and adhering to copyright regulations (Mhlanga, 2023). Students can seek guidance on properly attributing external materials, such

as images, videos, or written works, ensuring that their e-portfolios maintain integrity and uphold ethical standards. By emphasizing the significance of copyright and intellectual property, ChatGPT encourages students to become responsible digital citizens who respect the work of others.

Moreover, ChatGPT can guide students on the appropriate use of online resources when developing their e-portfolios. With the abundance of information available on the internet, students may need help in discerning reliable sources, evaluating credibility, and selecting appropriate content for their e-portfolios. ChatGPT can assist students in developing critical thinking skills, teaching them how to evaluate the quality and relevance of online resources (Cotton et al., 2023). It can provide tips and strategies for conducting effective research, fact-checking information, and utilizing trustworthy sources. By promoting information literacy, ChatGPT equips students with the skills necessary to navigate the vast online landscape and make informed choices regarding the content they include in their e-portfolios.

Furthermore, ChatGPT can address the issue of responsible online behaviour, including respectful interactions and appropriate communication. In developing their e-portfolios, students may encounter opportunities for collaboration, feedback, and engagement with others. ChatGPT can educate students on the principles of digital citizenship, emphasizing the importance of respectful and constructive online interactions (Adiguzel et al., 2023). It can guide netiquette, encouraging students to communicate courteously, offer constructive feedback, and engage in meaningful discussions. By promoting positive online behaviour, ChatGPT helps students cultivate a culture of respect and collaboration within the e-portfolio development process. By engaging with ChatGPT, students also develop a deeper understanding of the potential consequences of their online actions. ChatGPT can highlight the significance of online reputation management and the long-term impact of digital footprints. Students can learn how their e-portfolio content and online interactions may shape their digital identity and influence future opportunities. This knowledge empowers students to make conscious choices and exhibit responsible online behaviour, ensuring that their e-portfolios align with their desired professional image and personal values.

Potential Benefits

Enhanced Language Proficiency

Regarding bolstering writing accuracy, eportfolios prove advantageous as they harness the editing, spelling, and grammar-checking functionalities embedded within the eportfolio platform (Meshkat & Goli, 2012). There are plenty of options available through ChatGPT, and this tool can be an excellent aid for learners who build their eportfolios. This tool allows learners to understand and work through intricate topics when developing eportfolios. One of the most essential advantages of the Chat GPT system is that it can understand and respond to natural language questions.

Therefore, when using ChatGPT for eportfolios development, students can receive instant feedback on their language skills, such as grammar, pronunciation, and vocabulary (Rudolph et al., 2023). The ChatGPT model can help students develop their reading and writing skills by providing suggestions (e.g. syntactic and grammatical); the model can create practice exercises and quizzes for various subjects (e.g. mathematics, physics, language, and literature); and the model can provide a set of activities and quizzes.

Moreover, the ChatGPT model can create explanations and step-by-step solutions to a given problem; the model can help develop problem-solving skills and analytical and out-of-the-box thinking. Therefore, ChatGPT can act as the writing assistant for language learners when they establish eportfolios. The extensive linguistic dataset (Jiang et al., 2022) empowers ChatGPT to engage in intelligent communication, continuously learn from previous interactions, refine its abilities, and serve as tireless language-learning companions (Fryer et al., 2020; Kim, 2022). A wealth of input proves pivotal in successful second language acquisition, and AI-driven chatbots excel at providing linguistic information and daily conversation practice (Huang et al., 2022), igniting the interest of language learners (Gallacher et al., 2018) and contributing to their holistic development (Kohnke et al., 2023). Furthermore, these chatbots emphasize vital knowledge and address learners' queries, enabling them to notice and grasp linguistic nuances (Schmidt, 1990). With their availability, students can practice their language skills anytime, anywhere (Smutny & Schreiberova, 2020). Real-time assistance fosters learning by creating interactive opportunities (Ellis, 1997) and enabling learners to refine their communication output (Mackey, 2020). In the face of challenging input, AI-driven chatbots can adapt the proficiency level, offer personalized learning materials, and suggest tailored learning (Kuhail et al., 2023). These chatbots surpass human language partners by providing an array of expressions, questions, and vocabulary, thus fostering an authentic and interactive language-learning environment (Huang et al., 2022).

Improved Self-Regulated Learning

Thanks to ChatGPT, when building eportfolios, students can “take the initiative, with or without the help from others, in diagnosing their learning needs, formulating goals, identifying human and material re-choosing and implementing appropriate learning strategies, and evaluating learning outcomes” (Knowles, 1989, p. 18). This process also includes self-regulation learning, which comprises three pivotal phases (Bandura, 1977; Zimmerman, 2000). Bandura (1977) emphasizes the significance of self-observation, self-judgement, and self-reaction in regulating one's learning journey. Self-observation involves attentively observing one's behaviour, while self-judgement entails comparing one's performance against a standard, and self-reaction consists of responding to self-judgement in an evaluative manner (Bandura, 1977).

Similarly, Zimmerman (2000) asserts that self-regulation follows a cyclical pattern of three interconnected phases: forethought, performance, and self-reflection.

In the forethought phase, learners engage in processes and beliefs such as motivation, self-efficacy, goal setting, and planning to initiate their learning efforts. The performance phase encompasses attentional control, record-keeping, and monitoring, where students optimize their task performance. The self-reflection phase involves self-evaluation, wherein learners compare their performance to set goals and assess their outcomes (Zimmerman, 2000). Zimmerman (1986, 2000) proposes a set of questions to comprehend these phases better. In the forethought phase, learners may inquire about the timing and location of their writing, how to initiate the task, and what strategies would facilitate their writing process. During the performance phase, they may seek answers to questions such as whether they have achieved the assignment's objective if it is taking longer than expected, how to maintain motivation, and what support is needed. In the self-reflection phase, learners reflect on their performance and consider questions such as whether they performed well, how they stayed focused, what strategies aided them, whether they allocated sufficient time to complete the task if they employed effective study strategies, and whether they set appropriate rewards and consequences while adhering to their plans.

Additionally, instant constructive feedback can help motivate students, promoting self-directed learning (Sallang & Ling, 2019). When students build their eportfolios, ChatGPT can help to provide instant feedback and comments on their questions. This significantly motivates students to reduce procrastination and boost their process of developing eportfolios.

Increased Learner Engagement

Thanks to the ability to compare existing data that ChatGPT has been trained and generating from the logic language the users have fed when building eportfolios with ChatGPT, it can help to enhance the coherences of the content and also report the links between ideas from the student's products. Moreover, using chatbots provides students with immediate and specific feedback, which has enhanced their motivation and interest (Johnson et al., 2000). Students feel comfortable interacting with chatbots as they can freely ask questions without fearing judgement (Yadav et al., 2022). Incorporating chatbots in the classroom has increased students' enthusiasm and interest in learning. For instance, Liang et al. (2021) employed a chatbot to deliver prompt feedback to students in a programming course, significantly improving student motivation and engagement (St-Hilaire et al., 2022). Therefore, when students build their eportfolios, ChatGPT can deliver prompt feedback, which causes no fear of being judged or criticized. These AI-powered systems offer personalized assistance to students, aiming to enhance learning outcomes and student engagement. However, further research is necessary to explore the impact of AI technology on students' motivation and engagement, given its relatively new presence in the classroom (Parichahua et al., 2022). It is worth noting that before ChatGPT, technological applications in language teaching and instruction were already prevalent owing to decades of artificial intelligence research (Ali et al.,

2023). Wang and Guthrie (2004) conducted one of the earliest studies on the influence of technology in language programs, investigating whether students can access authentic communication experiences. Integrating computers and other advanced equipment significantly facilitates learning (Justo et al., 2022), fostering student engagement, motivation, and interest in acquiring a foreign language.

Personalized Learning Experiences

Learners can argue with ChatGPT about explanations, solutions, and other suggestions. Therefore, learners receive interactive help from ChatGPT anytime and anywhere. Educators can use ChatGPT to provide personalized learning support for their students. Depending on a student's needs and learning style, ChatGPT can suggest customized resources and learning activities. For instance, educators can use ChatGPT to analyse student performance data and identify areas where students struggle with particular concepts or algorithms. An educator might notice that a specific student is working with sorting algorithms. In this case, the educator can use ChatGPT to generate customized resources based on that student's learning style and abilities (e.g. a video tutorial on a specific sorting algorithm the student is struggling with or a coding exercise to reinforce that concept). Indeed, customized instructions that cater to students' interests can be achieved by allowing students to have a say in their learning pace (Zhang et al., 2020). This empowers students to take control of their learning journey based on their interests, passions, and aspirations that they choose to include in their eportfolios. It is particularly beneficial for self-directed and self-regulated learners who can monitor their progress towards learning goals while collaborating with teachers to design the learning environment. Students can embrace the principles of voice, co-creation, social interaction, and self-discovery (Kallick & Zmuda, 2017).

Personalized learning aims to provide individual support to students, but teachers often face challenges in recognizing and addressing students' specific needs and abilities. The diverse range of student preferences presents a challenge in delivering formal personalized learning, prompting the search for alternative methods (Abbott et al., 2014). Fortunately, technology plays a significant role in addressing this issue. Intelligent learning systems, incorporating learner preferences and assessing individual learning data, have made personalized learning achievable (Han et al., 2021; Ingkavara et al., 2022; Troussas et al., 2021; Xie et al., 2019). However, more than technology is needed for creating a personalized learning environment. Other factors, such as students' characteristics, the learning process, social interaction, guidance and feedback, learning profile, and institutional support, are also vital for the success of personalized learning systems (Li & Wong, 2021).

Challenges and Limitations

Dependence on Technology

With the advancing prowess and widespread adoption of AI language models, the spectre of overreliance on AI-generated content for communication, decision-making, and information consumption looms. Such dependency carries the peril of diminishing critical thinking, stifling creativity, and undervaluing human-generated content. Tackling this hurdle necessitates championing a harmonious approach to utilizing AI-generated content while nurturing media literacy to empower users in distinguishing between human-authored and AI-crafted content. Farrokhnia et al. (2023) argued that the utilization of ChatGPT has the propensity to engender a sense of laziness and indifference among humans, perpetuating an overreliance on the information it generates. Therefore, with ChatGPT for eportfolio development, teachers and students could experience the downfall of their thinking skills, especially critical thinking skills.

Additionally, the findings derived from the questionnaire shed light upon the extensive utilization of ChatGPT, a testament to its widespread adoption. Its seamless user experience and ubiquitous availability across various platforms have rendered ChatGPT a transformative force within the academic sphere, revolutionizing the integration of AI. Nonetheless, an apprehension arises, for students run the risk of excessively relying on ChatGPT for quandary resolution and knowledge acquisition, thereby impeding the cultivation of critical thinking prowess and self-sufficiency. As a result, the imperative lies in striking a delicate balance, harnessing the potential of ChatGPT in developing eportfolios while nurturing the development of essential cognitive faculties and independent learning capabilities to be more self-directed (Sánchez-Ruiz et al., 2023).

Ethical Considerations

In the realm of ethical considerations surrounding the integration of ChatGPT in education, a contentious debate emerges, encompassing apprehensions regarding potential cheating implications and the broader impact on assessment practices. However, introducing detection tools targeting AI-generated text can be an ongoing challenge rather than addressing the issue (Cassidy, 2023). Moreover, this approach must delve into the core aspects of ChatGPT's utility and the broader ethical implications of technology utilization in educational contexts. Therefore, it raises questions of ethical issues when both teachers and students implement ChatGPT in eportfolio development.

Generating these questions requires critical examination and consideration of their alignment with pedagogical goals, assessment frameworks, and the overall instructional context. In addition, the utilization of copious amounts of textual data for model training evokes concerns surrounding latent biases imprinted within the

model's algorithms. The training data, reflecting existing societal preferences, harbours the risk of perpetuating them, necessitating scrutiny and intervention (Cascella et al., 2023). Evaluating the effectiveness and appropriateness of ChatGPT-generated issues is crucial to ensuring their relevance and educational value within the learning environment. This difficulty could present additional challenges for educators who employ eportfolios in their instructional endeavours. From the perspective of learners, as they embark on developing their eportfolios, they face a myriad of considerations and decisions to navigate the generated information, especially some sensitive topics, such as race, gender, or socioeconomic status (Parray et al., 2023). Notably, using ChatGPT to develop eportfolios could lead to some biases that are closely related to the model's algorithms, which was put forward by Ray (2023):

ChatGPT, like other AI language models, is susceptible to various biases, including gender, racial, and cultural biases, language bias, and ideological bias. These biases stem from the model's training data, which reflects human-generated content from the Internet. Other biases, such as attention, format, and commercial biases, can also emerge from the nature of the training data. ChatGPT has several biases as follows: (i) gender, racial, and cultural biases, (ii) language bias, (iii) ideological bias, (iv) sensationalism and clickbait bias, (v) confirmation bias, (vi) temporal bias, (vii) exclusionary bias, (viii) commercial bias, (ix) cognitive bias, (x) attention bias, (xi) format bias, (xii) source bias, (xiii) novelty bias, (xiv) positive/negative sentiment bias, (xv) outlier bias, (xvi) implicit bias, (xvii) authority bias, (xviii) recency bias, (xix) groupthink bias, (xx) anchoring bias, (xxi) availability bias, (xxii) false consensus bias, (xxiii) hindsight bias. (pp. 147–148)

To harness the full potential of ChatGPT, it becomes imperative to possess a substantial reservoir of knowledge, enabling the identification of any potential errors and diligently verifying its output for utmost precision.

An additional salient ethical concern pertains to the privacy and security of data encompassing the portfolios of both educators and learners. Using ChatGPT and analogous generative models necessitates gathering and manipulating personal information, thereby inciting privacy and data security apprehensions. It becomes paramount to institute appropriate measures to alleviate the potential risks associated with unauthorized entities gaining access to sensitive personal data, including private daily journals, diaries, or photos, which students post on their eportfolios. Safeguarding the sanctity and confidentiality of individual data must be given the highest precedence, mandating the implementation of comprehensive safeguards to ascertain its inviolability. By employing robust security protocols and incorporating stringent protective mechanisms, the potential vulnerabilities related to unauthorized intrusion can be effectively mitigated, engendering an environment of trust and assurance about handling such generative models and the data they entail.

Furthermore, being manipulated emotionally and persuaded is another crucial factor of ethical consideration when implementing ChatGPT in building eportfolios. Advanced AI language models, like ChatGPT, can generate content which has a strong emotional appeal or is highly convincing. This capability has ethical issues because AI-generated content can manipulate people's emotions, beliefs, and actions or spread false information. Countering the misuse of AI systems by constructing and using them responsibly is a significant ethical concern.

Ensuring Quality of Feedback

Regarding data access, ChatGPT possesses an extensive repertoire; however, it exhibits limitations in common sense comprehension, occasionally producing technically accurate yet nonsensical responses within the real-world context. As a language model with a general-purpose nature, ChatGPT may fail to deliver personalized feedback that aligns precisely with individual users' unique requirements and learning objectives. Consequently, its efficacy in educational or coaching settings, where tailored guidance is paramount, may need to be improved. The discrepancy between ChatGPT's proficiency in accessing data and its capacity to apply personalized insights poses a challenge in maximizing its potential within educational and coaching domains (Ray, 2023). Therefore, although ChatGPT can give instant feedback, its quality could be better. If educators who conduct eportfolios in their classroom apply those feedbacks to their students' products and progress, it could cause some nonsensical responses.

Potential for Plagiarism

Another area of inquiry revolves around the originality of ChatGPT's responses. ChatGPT needs to provide explicit sources or citations; questions arise regarding the authenticity and potential reliance on unattributed sources. The responses generated by ChatGPT might be partially original but rather paraphrases derived from external sources without appropriate citation, raising concerns of potential plagiarism (Cassidy, 2023). The need for more transparency in source attribution within ChatGPT's output raises significant questions regarding academic integrity and adherence to scholarly standards. The advent of AI-generated content poses a quandary wherein its utilization in task completion and extracurricular endeavours risks impeding the learning process and compromising the attainment of vital proficiencies. Notably, the outcomes gleaned evince a conspicuous prevalence of this tool within the academic sphere, underscoring its adoption for task fulfilment and assignment completion. Albeit students' perceptions negate the purported impact on skill assimilation, the veritable veracity might deviate markedly, necessitating temporal intricacies in accurately gauging the repercussions on the learning trajectory.

Technical Accessibility

Given the current landscape, a heightened emphasis is placed on cultivating students' digital competence. Traditionally, educational institutions have prioritized equipping students with foundational technological skills, encompassing the utilization of e-platforms (e.g. Padlet, Google Docs), e-portfolios, and video production tools. However, in light of rapid digital advancements, scholars have underscored the necessity for more advanced digital competence among students. The advent of ChatGPT intensifies this imperative. To effectively employ ChatGPT as a learning

tool, students must be aware of its limitations, exercise prudent and ethical usage, and embrace their roles as responsible digital citizens. Crucially, education departments, universities, and schools must establish comprehensive guidelines governing the utilization of such tools, adapt their teaching and assessment methodologies, and proactively prepare students for a future where AI-driven digital tools constitute an integral aspect of daily existence.

Inability to fact-check or access real-time information: ChatGPT's knowledge is limited to the data it was trained on, with a cutoff date of 2021. As a result, it cannot provide real-time information or verify the accuracy of its responses against new developments or updates.

Conclusion

This chapter has examined how ChatGPT can be incorporated into the e-portfolio process and how it can help students enhance their learning experiences and support their growth and success. With its simple and user-friendly platform, ChatGPT enables students to ask questions, receive prompt responses, and benefit from real-time feedback, reducing the workload for teachers and fostering students' autonomy in developing e-portfolios. It also facilitates a supportive and controlled environment that can enable online communication responsibility and provide essential guidance on ethical practices throughout the e-portfolio journey.

The benefits of using ChatGPT for e-portfolio development are diverse. Language proficiency, self-regulated learning, learner engagement, and personalized learning experiences can be enhanced. However, it has challenges and limitations. Dependence on technology raises concerns about technical accessibility and the risks of technical difficulties. Ethical considerations may also arise regarding the responsible use of AI, the quality of feedback provided by ChatGPT, and the potential for plagiarism. With careful consideration of the ethical implications and appropriate implementation strategies, ChatGPT can be a valuable tool for developing e-portfolios in ESL classrooms, contributing to students' growth, and fostering their digital literacy skills.

References

- Abbott, J., Basham, J., Nordmark, S., Schneiderman, M., Umpstead, B., Walter, K., & Wolf, M. A. (2014). *Technology-enabled personalized learning findings & recommendations to accelerate implementation*. https://www.fi.ncsu.edu/wp-content/uploads/2014/02/TEPLS_report-FINAL-051415.pdf
- Abdelghani, R., Wang, Y.-H., Yuan, X., Wang, T., Lucas, P., Sauz on, H., & Oudeyer, P.-Y. (2022). *GPT-3-driven pedagogical agents for training children's curious question-asking skills*. <https://doi.org/10.48550/ARXIV.2211.14228>.

- Abdullah, M., Madain, A., & Jararweh, Y. (2022). *ChatGPT: Fundamentals, applications and social impacts*. 2022 ninth international conference on social networks analysis, management and security (SNAMS), pp. 1–8. <https://doi.org/10.1109/SNAMS58071.2022.10062688>.
- Adiguzel, T., Kaya, M. H., & Cansu, F. K. (2023). Revolutionizing education with AI: Exploring the transformative potential of ChatGPT. *Contemporary Educational Technology*, 15(3), ep429. <https://doi.org/10.30935/cedtech/13152>
- Alanazi, S. M., & Bensalem, E. (2022). Undergraduate research EFL students' experiences in building ePortfolios. *Multidisciplinary Journal for Education, Social and Technological Sciences*, 9(2), 1–22. <https://doi.org/10.4995/muse.2022.17167>
- Al-Naibi, I., Al-Jabri, M., & Al-Kalbani, I. (2018). Promoting students' paragraph writing using EDMODO: An action research. *TOJET: The Turkish Online Journal of Educational Technology*, 17(1), 130–143.
- Ali, J. K. M., Shamsan, M. A. A., Hezam, T. A., & Mohammed, A. A. Q. (2023). Impact of ChatGPT on learning motivation. *Journal of English Studies in Arabia Felix*, 2(1), 41–49. <https://doi.org/10.56540/jesaf.v2i1.51>
- Badini, S., Regondi, S., Frontoni, E., & Pugliese, R. (2023). Assessing the capabilities of ChatGPT to improve additive manufacturing troubleshooting. *Advanced Industrial and Engineering Polymer Research*, S2542504823000192. <https://doi.org/10.1016/j.aiepr.2023.03.003>
- Baidoo-Anu, D., & Owusu Ansah, L. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4337484>
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215. <https://doi.org/10.1037/0033-295X.84.2.191>
- Bao, M. (2019). Can home use of speech-enabled artificial intelligence mitigate foreign language anxiety – Investigation of a concept. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3431734>
- Baris, M. F., & Tosun, N. (2011). E-portfolio in lifelong learning applications. 28, 522–525. <https://doi.org/10.1016/j.sbspro.2011.11.100>.
- Barret, H. (2004). Electronic portfolios. *Education and Technology*, 1, 381–387.
- Barrett, H. (2000). Electronic teaching portfolios: Multimedia skills + portfolio development = powerful professional development. In D. Willis, J. Price & J. Willis (Eds.), *Proceedings of SITE 2000--Society for Information Technology & Teacher Education International Conference* (pp. 1111–1116). Association for the Advancement of Computing in Education (AACE). <https://www.learntechlib.org/primary/p/15787>
- Barrett, H. C. (2007). Researching electronic portfolios and learner engagement: The REFLECT initiative. *Journal of Adolescent & Adult Literacy*, 50(6), 436–449.
- Barrot, J. S. (2016). Using Facebook-based e-portfolio in ESL writing classrooms: Impact and challenges. *Language, Culture and Curriculum*, 29(3), 286–301. <https://doi.org/10.1080/07908318.2016.1143481>
- Barrot, J. S. (2019). Facebook as an e-portfolio platform in the EFL/ESL writing classrooms. In S. Ballweg & B. Kühn (Eds.), *Portfolioarbeit im Kontext von Sprachenunterricht* (pp. 115–130). Göttingen University Press. <https://doi.org/10.17875/gup2019-1204>
- Barrot, J. S. (2020). Effects of Facebook-based e-portfolio on ESL learners' writing performance. *Language, Culture and Curriculum*, 34(1), 95–111. <https://doi.org/10.1080/07908318.2020.1745822>
- Barrot, J. S. (2021). Effects of Facebook-based e-portfolio on ESL learners' writing performance. *Language, Culture and Curriculum*, 34(1), 95–111. <https://doi.org/10.1080/07908318.2020.1745822>
- Barrot, J. S. (2023). Using ChatGPT for second language writing: Pitfalls and potentials. *Assessing Writing*, 57, 100745. <https://doi.org/10.1016/j.asw.2023.100745>
- Baturay, M. H., & Daloglu, A. (2010). E-portfolio assessment in an online English language course. *Computer Assisted Language Learning*, 23(5), 413–428. <https://doi.org/10.1080/09588221.2010.520671>

- Bauer, E., Greisel, M., Kuznetsov, I., Berndt, M., Kollar, I., Dresel, M., Fischer, M. R., & Fischer, F. (2023). Using natural language processing to support peer-feedback in the age of artificial intelligence: A cross-disciplinary framework and a research agenda. *British Journal of Educational Technology*, 13336. <https://doi.org/10.1111/bjjet.13336>
- Bernius, J. P., Krusche, S., & Bruegge, B. (2022). Machine learning based feedback on textual student answers in large courses. *Computers and Education: Artificial Intelligence*, 3, 100081. <https://doi.org/10.1016/j.caeai.2022.100081>
- Cascella, M., Montomoli, J., Bellini, V., & Bignami, E. (2023). Evaluating the feasibility of ChatGPT in healthcare: An analysis of multiple clinical and research scenarios. *Journal of Medical Systems*, 47(1), 33. <https://doi.org/10.1007/s10916-023-01925-4>
- Cassidy, C. (2023). Australian universities to return to ‘pen and paper’ exams after students caught using AI to write essays. *The Guardian Online*. <https://www.theguardian.com/australia-news/2023/jan/10/universities-to-return-to-pen-and-paper-exams-after-students-caught-using-ai-to-write-essays>
- Chang, C.-C. (2008). Enhancing self-perceived effects using web-based portfolio assessment. *Computers in Human Behavior*, 24(4), 1753–1771. <https://doi.org/10.1016/j.chb.2007.07.005>
- Cheng, G. (2008). Implementation challenges of the English language eportfolio system from various stakeholder perspectives. *Journal of Educational Technology Systems*, 37(1), 97–118. <https://doi.org/10.2190/ET.37.1.h>
- Cotton, D. R. E., Cotton, P. A., & Shipway, J. R. (2023). Chatting and cheating: Ensuring academic integrity in the era of ChatGPT. *Innovations in Education and Teaching International*, 1–12. <https://doi.org/10.1080/14703297.2023.2190148>
- Crawford, J., Cowling, M., & Allen, K.-A. (2023). Leadership is needed for ethical ChatGPT: Character, assessment, and learning using artificial intelligence (AI). *Journal of University Teaching and Learning Practice*, 20(3). <https://doi.org/10.53761/1.20.3.02>
- Deng, J., & Lin, Y. (2023). The benefits and challenges of ChatGPT: An overview. *Frontiers in Computing and Intelligent Systems*, 2(2), 81–83. <https://doi.org/10.54097/fcis.v2i2.4465>
- Dijkstra, R., Genç, Z., Kayal, S., & Kamps, J. (2022). Reading comprehension quiz generation using generative pre-trained transformers, pp. 4–17. <https://github.com/RamonDijkstra/EduQuiz>
- Ellis, R. (1997). *Second language acquisition* (pp. 98–98). OUP.
- Ersnova, V., Gerasimova, I., & Kapuza, A. (2021). Math is not for girl? Investigating the impact of e-learning platforms on the development of growth mindsets in elementary classrooms. *Voprosy Obrazovaniya/Educational Studies Moscow*, 3, 91–113. <https://doi.org/10.17323/1814-9545-2021-3-91-113>
- EUFolio. (2015). *EU classroom ePortfolios pilot evaluation results*. EUFolio.
- Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2023). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, 1–15. <https://doi.org/10.1080/14703297.2023.2195846>
- Fathali, S., & Okada, T. (2016). On the importance of out-of-class language learning environments: A case of a web-based E-portfolio system enhancing reading proficiency. *International Journal on Studies in English Language and Literature*, 4(8). <https://doi.org/10.20431/2347-3134.0408011>
- Fryer, L. K., Coniam, D., Carpenter, R., & Lăpuşneanu, D. (2020). Bots for language learning now: Current and future directions. *Language Learning & Technology*, 24(2), 8–22.
- Gallacher, A., Thompson, A., & Howarth, M. (2018). “My robot is an idiot!” – Students’ perceptions of AI in the L2 classroom. In *Future-proof CALL: Language learning as exploration and encounters – Short papers from EUROCALL 2018* (pp. 70–76). [Research-publishing.net. https://doi.org/10.14705/rpnet.2018.26.815](https://doi.org/10.14705/rpnet.2018.26.815)
- Han, J., Kim, K. H., Rhee, W., & Cho, Y. H. (2021). Learning analytics dashboards for adaptive support in face-to-face collaborative argumentation. *Computers & Education*, 163, 104041. <https://doi.org/10.1016/j.compedu.2020.104041>
- Huang, H.-T. D., & Hung, S.-T. A. (2010). Effects of electronic portfolios on EFL oral performance. *Asian EFL Journal*, 12(2), 192–212.

- Huang, W., Hew, K. F., & Fryer, L. K. (2022). Chatbots for language learning—Are they really useful? A systematic review of chatbot-supported language learning. *Journal of Computer Assisted Learning*, 38(1), 237–257. <https://doi.org/10.1111/jcal.12610>
- Ingvavara, T., Panjaburee, P., Srisawasdi, N., & Sajjapanroj, S. (2022). The use of a personalized learning approach to implementing self-regulated online learning. *Computers and Education: Artificial Intelligence*, 3, 100086. <https://doi.org/10.1016/j.caeai.2022.100086>
- Iskender, A. (2023). Holy or unholy? Interview with open AI's ChatGPT. *European Journal of Tourism Research*, 34, 3414. <https://doi.org/10.54055/ejtr.v34i.3169>
- Ivanova, O. V. (2017). The use of e-portfolio to develop English language learners' autonomy and independence. *Information Technologies and Learning Tools*, 60(4), 155–165.
- Javaid, M., Haleem, A., Singh, R. P., Khan, S., & Khan, I. H. (2023). Unlocking the opportunities through ChatGPT tool towards ameliorating the education system. *Bench Council Transactions on Benchmarks, Standards and Evaluations*, 100115–100115. <https://doi.org/10.1016/j.tbench.2023.100115>
- Jenson, J. D., & Treuer, P. (2014). Defining the e-portfolio: What it is and why it matters. *Change: The Magazine of Higher Learning*, 46(2), 50–57. <https://doi.org/10.1080/00091383.2014.897192>
- Jiang, H., Cheng, Y., Yang, J., & Gao, S. (2022). AI-powered chatbot communication with customers: Dialogic interactions, satisfaction, engagement, and customer behavior. *Computers in Human Behavior*, 134, 107329–107329. <https://doi.org/10.1016/j.chb.2022.107329>
- Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education*. <http://www.isi.eduuisddcarte>
- Justo, R. C., Ramos, R. F., Llandelar, S. M. R., Sanares, R. N., & Rodelas, N. C. (2022). Game-based learning for student engagement: A paradigm shift in blended learning education. 050002. <https://doi.org/10.1063/5.0109625>.
- Kabilan, M. K., & Khan, M. A. (2012). Assessing pre-service English language teachers' learning using e-portfolios: Benefits, challenges and competencies gained. *Computers and Education*, 58(4), 1007–1020. <https://doi.org/10.1016/j.compedu.2011.11.011>
- Kallick, B., & Zmuda, A. (2017). *Students at the center: Personalized learning with habits of mind*. ASCD.
- Kangasharju, A., Ilomäki, L., Lakkala, M., & Toom, A. (2022). Lower secondary students' poetry writing with the AI-based poetry machine. *Computers and Education: Artificial Intelligence*, 3. <https://doi.org/10.1016/j.caeai.2022.100048>
- Kim, K.-J. (2022). Moving forward: Embracing challenges as opportunities to improve medical education in the post-COVID era. *Humanities and Social Sciences Communications*, 9(1), 419–419. <https://doi.org/10.1057/s41599-022-01451-7>
- Knowles, M. S. (1989). *The making of an adult educator: An autobiographical journey*. Jossey-Bass.
- Kohnke, L., Moorhouse, B. L., & Zou, D. (2023). ChatGPT for language teaching and learning. *RELC Journal*, 003368822311628. <https://doi.org/10.1177/00336882231162868>
- Kuhail, M. A., Alturki, N., Alramlawi, S., & Alhejori, K. (2023). Interacting with educational chatbots: A systematic review. *Education and Information Technologies*, 28(1), 973–1018. <https://doi.org/10.1007/s10639-022-11177-3>
- Kung, T. H., Cheatham, M., Medenilla, A., Sillos, C., De Leon, L., Elepaño, C., Madriaga, M., Aggabao, R., Diaz-Candido, G., Maningo, J., & Tseng, V. (2023). Performance of ChatGPT on USMLE: Potential for AI-assisted medical education using large language models. *PLOS Digital Health*, 2(2), e0000198. <https://doi.org/10.1371/journal.pdig.0000198>
- Kusuma, I. P. I., Mahayanti, N. W. S., Adnyani, L. D. S., & Budiarta, L. G. R. (2021). Incorporating E-portfolio with flipped classrooms: An in-depth analysis of students' speaking performance and learning engagement. *JALT CALL Journal*, 17(2), 93–111. <https://doi.org/10.29140/JALTCALL.V17N2.378>
- Le, A. N. N., Bo, L. K., & Nguyen, N. M. T. (2023). *Canva-based e-portfolio in L2 writing instructions: Investigating the effects and students' attitudes*. *Computer Assisted Language Learning Electronic Journal (CALL-EJ)*, 42(1), 41–62.

- Li, K. C., & Wong, B. T.-M. (2021). Features and trends of personalized learning: A review of journal publications from 2001 to 2018. *Interactive Learning Environments*, 29(2), 182–195. <https://doi.org/10.1080/10494820.2020.1811735>
- Li, L., Zhang, H. Y., & Gai, Y. M. (2013). *Application of E-portfolio in listening course for english majors*, pp. 352–354. <https://doi.org/10.1109/ICCIS.2013.100>.
- Liang, Y., Meng, F., Zhang, Y., Chen, Y., Xu, J., & Zhou, J. (2021). Infusing multi-source knowledge with heterogeneous graph neural network for emotional conversation generation. *Proceedings of the AAAI Conference on Artificial Intelligence*, 35(15), 13343–13352. <https://doi.org/10.1609/aaai.v35i15.17575>
- Mackey, A. (2020). *Interaction, feedback and task research in second language learning: Methods and design*. Cambridge University Press.
- Meshkat, M., & Goli, A. (2012). Effect of using e-portfolio on the writing proficiency of Iranian EFL learners. *The Iranian EFL Journal*, 8(5), 337–370.
- Meyer, E., Abrami, P. C., Wade, C. A., Aslan, O., & Deault, L. (2010). Improving literacy and metacognition with electronic portfolios: Teaching and learning with ePEARL. *Computers & Education*, 55(1), 84–91. <https://doi.org/10.1016/j.compedu.2009.12.005>
- Mhlanga, D. (2023). Open AI in education, the responsible and ethical use of ChatGPT towards lifelong learning. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4354422>
- Ngui, W., Pang, V., & Hiew, W. (2022). E-portfolio as an academic writing assessment tool in higher education: Strengths and challenges. *Indonesian Journal of Applied Linguistics*, 12(2), 556–568. <https://doi.org/10.17509/ijal.v12i2.40122>
- OpenAI. (n.d.). *Introducing ChatGPT*. <https://openai.com/blog/chatgpt#OpenAI>
- Paricahua, E. W. P., Muñoz, S. A. S., Paricahua, A. K. P., Arias-González, J. L., Mamani, W. C., Guzman, C. J. A., Flores, W. H. B., Lipa, J. P. T., Velasquez, Z. V., Cáceres-Chávez, M. d. R., & Carranza, C. P. M. (2022). Research competencies: A comparative study in public and private universities. *Eurasian Journal of Educational Research*, 2022(99), 297–312. <https://doi.org/10.14689/ejer.2022.99.018>
- Parray, A. A., Inam, Z. M., Ramonfaur, D., Haider, S. S., Mistry, S. K., & Pandya, A. K. (2023). ChatGPT and global public health: Applications, challenges, ethical considerations and mitigation strategies. *Global Transitions*, 5, 50–54. <https://doi.org/10.1016/j.glt.2023.05.001>
- Paulson, F. L., Paulson, P. R., & Meyer, C. A. (1991). What makes a portfolio a portfolio? Eight thoughtful guidelines will help educators encourage self-directed learning. *Educational Leadership*, 48(5), 60–63.
- Pavlik, J. V. (2023). Collaborating with ChatGPT: Considering the implications of generative artificial intelligence for journalism and media education. *Journalism & Mass Communication Educator*, 78(1), 84–93. <https://doi.org/10.1177/10776958221149577>
- Purwanti, T. T. (2015). The implementation of self-assessment in writing class: A case study at STBA LIA Jakarta. *TEFLIN Journal*, 26(1), 97–97. <https://doi.org/10.15639/teflinjournal.v26i1/97-116>
- Ray, P. P. (2023). ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope. *Internet of Things and Cyber-Physical Systems*, 3, 121–154. <https://doi.org/10.1016/j.iotcps.2023.04.003>
- Rojas-Kramer, C., Esquivel-Gómez, I., & García-Santillán, A. (2015). Educational use of Facebook in higher-education environments: Current practices and guidelines. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *INTED2015 Proceedings* (pp. 6042–6052). IATED Academy. <https://library.iated.org/view/ROJASKRAMER2015EDU>
- Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching*, 6(1). <https://doi.org/10.37074/jalt.2023.6.1.9>
- Sallang, H., & Ling, Y.-L. (2019). The importance of immediate constructive feedback on students' instrumental motivation in speaking in English. *Britain International of Linguistics Arts and Education (BioLAE) Journal*, 1(2), 1–7. <https://doi.org/10.33258/biolae.v1i2.58>
- Sánchez-Ruiz, L. M., Moll-López, S., Nuñez-Pérez, A., Moraño-Fernández, J. A., & Vega-Fleitás, E. (2023). ChatGPT challenges blended learning methodologies in engineering educa-

- tion: A case study in mathematics. *Applied Sciences*, 13(10), 6039. <https://doi.org/10.3390/app13106039>
- Sarsa, S., Denny, P., Hellas, A., & Leinonen, J. (2022). *Automatic generation of programming exercises and code explanations using large language models*, pp. 27–43. <https://doi.org/10.1145/3501385.3543957>.
- Schmidt, R. W. (1990). The role of consciousness in second language learning1. *Applied Linguistics*, 11(2), 129–158.
- Slepecevic-Zach, P., & Stock, M. (2018). EPortfolio as a tool for reflection and self-reflection. *Reflective Practice*, 19(3), 291–307. <https://doi.org/10.1080/14623943.2018.1437399>
- Smutny, P., & Schreiberova, P. (2020). Chatbots for learning: A review of educational chatbots for the Facebook Messenger. *Computers & Education*, 151, 103862–103862.
- St-Hilaire, F., Vu, D. D., Frau, A., Burns, N., Faraji, F., Potochny, J., Robert, S., Roussel, A., Zheng, S., Glazier, T., Romano, J. V., Belfer, R., Shayan, M., Smofsky, A., Delarosbil, T., Ahn, S., Eden-Walker, S., Sony, K., Ching, A. O., Sabina Elkins, Anush Stepanyan, Adela Matajova, Victor Chen, Hossein Sahraei, Robert Larson, Nadia Markova, Andrew Barkett, Laurent Charlin, Yoshua Bengio, Iulian Vlad Serban Kochmar, E. (2022). *A new era: Intelligent tutoring systems will transform online learning for millions*. <http://arxiv.org/abs/2203.03724>
- Stefani, L., Mason, R., & Pegler, C. (2007). *The educational potential of e-portfolios: Supporting personal development and reflective*. Routledge.
- Suparjan, S., & Mariyadi, M. (2021). Google classroom as a distance learning media: Limitations and overcoming efforts. *AL-ISHLAH: Jurnal Pendidikan*, 13(1), 407–416. <https://doi.org/10.35445/alishlah.v13i1.460>
- Thang, S. M., Lee, Y. S., & Zulkifli, N. F. (2012). The role of the electronic portfolio in enhancing information and communication technology and English language skills: The voices of six Malaysian undergraduates. *Computer Assisted Language Learning*, 25(3), 277–293. <https://doi.org/10.1080/09588221.2012.655299>
- Tlili, A., Shehata, B., Adarkwah, M. A., Bozkurt, A., Hickey, D. T., Huang, R., & Agyemang, B. (2023). What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education. *Smart Learning Environments*, 10(1), 15. <https://doi.org/10.1186/s40561-023-00237-x>
- Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). A novel teaching strategy through adaptive learning activities for computer programming. *IEEE Transactions on Education*, 64(2), 103–109. <https://doi.org/10.1109/TE.2020.3012744>
- Uí Choistealbha, J. (2018). The benefits and challenges of using ePortfolios—HAMK unlimited. *HAMK Unlimited Journal*. <https://unlimited.hamk.fi/ammattilinen-osaaminen-ja-opetus/the-benefits-and-challenges-of-using-eportfolios/>
- Walland, E., & Shaw, S. (2022). E-portfolios in teaching, learning and assessment: Tensions in theory and praxis. *Technology, Pedagogy and Education*, 31(3), 363–379. <https://doi.org/10.1080/1475939X.2022.2074087>
- Wang, J. H.-Y., & Guthrie, J. T. (2004). Modeling the effects of intrinsic motivation, extrinsic motivation, amount of reading, and past reading achievement on text comprehension between U.S. and Chinese students. *Reading Research Quarterly*, 39(2), 162–186. <https://doi.org/10.1598/RRQ.39.2.2>
- Xie, H., Chu, H.-C., Hwang, G.-J., & Wang, C.-C. (2019). Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017. *Computers & Education*, 140, 103599. <https://doi.org/10.1016/j.compedu.2019.103599>
- Yadav, S., Kaushik, A., & Sharma, S. (2022). *Simplify the difficult: Artificial intelligence and cloud computing in healthcare* (pp. 101–124). https://doi.org/10.1007/978-3-030-73885-3_7.
- Yastibas, A. E., & Cepik, S. (2015). Teachers' attitudes toward the use of e-portfolios in speaking classes in English language teaching and learning. *Procedia – Social and Behavioral Sciences*, 176, 514–525. <https://doi.org/10.1016/J.SBSPRO.2015.01.505>
- Zhang, L., Basham, J. D., & Yang, S. (2020). Understanding the implementation of personalized learning: A research synthesis. *Educational Research Review*, 31, 100339. <https://doi.org/10.1016/j.edurev.2020.100339>

- Zhu, J.-J., Jiang, J., Yang, M., & Ren, Z. J. (2023). ChatGPT and environmental research. *Environmental Science & Technology*. <https://doi.org/10.1021/acs.est.3c01818>
- Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Educational Psychology*, *11*(4), 307–313.
- Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In *Handbook of self-regulation* (pp. 13–39). Elsevier.

Chapter 4

Exploring the Use of Alexa as a Motivational Tool in English Language Learning Among EFL Students in Israel



Ela Luria 

Introduction

In the ever-evolving landscape of education, the concept of future-oriented pedagogy has gained substantial importance. This pedagogical approach aims to address the current educational needs while equipping learners with skills and tools that will remain relevant in the face of an uncertain future. In this context, technology emerges as a promising solution, offering innovative pathways for pedagogical advancement. One remarkable facet of this technological revolution is computer-assisted language learning (CALL). As articulated by Nunan and Richards (2015), CALL has the potential to provide authentic and meaningful language learning opportunities.

Within the broader spectrum of CALL, Intelligent Computer-Assisted Language Learning (ICALL) amalgamates natural language processing and artificial intelligence, promising new avenues for enhanced language acquisition (Levy, 1997). One such revolutionary innovation in this domain is the integration of AI-powered virtual assistants, such as Alexa, into language classrooms. These AI-driven tools usher in interactive and personalized learning experiences, potentially reshaping how language learners interact with and master their target language. However, amid this technological promise, a conspicuous gap exists—comprehensive empirical research investigating the experiences and benefits of integrating AI assistants in language learning settings.

This article fills this void by presenting a study that delves into the experiences and perceived advantages of using Alexa during English as a foreign language (EFL) lessons. Employing a qualitative approach, this research harnesses

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semi-structured interviews to garner profound insights from EFL students who have incorporated Alexa into their language learning journey. These insights are grouped into themes encompassing students' experiences, motivation, confidence, engagement, and perceived benefits stemming from using Alexa as an educational tool.

The outcomes of this study unveil a noteworthy revelation: Coteaching with Alexa can significantly influence students' motivation to master the English language. Participants candidly report that interacting with Alexa in English enhances their confidence and imbues their learning process with newfound engagement. They value the non-judgmental environment that Alexa fosters, allowing them to practice their language skills and receive immediate feedback. Additionally, students acknowledge vital benefits, including vocabulary expansion, improved pronunciation, enhanced grammar skills, heightened listening comprehension, and the invaluable asset of immediate feedback.

These findings enrich the existing literature on technology integration in language education, underscoring the remarkable potential of AI-assisted language learning. As we delve deeper into the experiences and perceived benefits of employing AI assistants like Alexa, a trove of insights is unlocked—insights that hold profound relevance for educators, curriculum developers, and policymakers who aspire to elevate language learning outcomes in an increasingly technology-driven educational landscape.

Literature Review

Language Learning Theories and AI Alexa

This section in the literature review examines the relationship between language learning theories and the application of AI, mainly focusing on using the interactive personal assistant (IPA), Alexa. This review highlights the potential benefits of integrating AI technology into language education by investigating critical theories such as the interaction hypothesis, natural approach, acquisition versus learning hypothesis, information processing theory, and teaching/learning approaches. Additionally, it explores how AI, including Alexa, can serve as a motivational tool to enhance learners' engagement and motivation throughout language learning.

The Interaction Hypothesis and IPA

In language acquisition, the interaction hypothesis highlights the significance of comprehensible input, mainly when learners engage in negotiations for meaning. As Ghaemi and Salehi (2014) point out, today's prevailing belief is that language development occurs through interaction and the negotiation of meaning. This very characteristic of interaction and negotiation is also evident when interacting with

Alexa. Interactions with Alexa often involve negotiations for meaning, fostering a dynamic language learning experience. As Dizon (2020) explains, from an interactionist perspective, interactive personal assistants (IPAs) like Alexa can be valuable tools for language learning, as they encourage interactions in the second language and can help learners identify gaps in their linguistic knowledge and pronunciation (p. 16).

According to Long (1981), the input's nature might change when learners interact by negotiations around meaning. During negotiations for meaning, there will be explicit and implicit feedback, such as confirmation checks, comprehension checks, and clarification requests. According to the interaction hypotheses, many interactions lead to negative evidence, where the learners say something the interlocutors do not comprehend. However, after negotiations, the interlocutors may model the correct language. As an IPA, Alexa can give feedback to the learner on his attempt at output, such as confirmation checks and clarification checks; this ability allows for the interaction to feel authentic. By corrective feedback, students can 'notice the gap' between the observed input and their production (Schmidt & Frota, 1986, p. 310).

The interaction hypothesis comprises four constructs: input, interaction, feedback, and output. Traditionally, these constructs were limited only to face-to-face human interaction; however, nowadays, they relate to interactions with artificial intelligence (Long 1981). According to Lightbown (2000), language learning in the classroom only sometimes allows for input and output interaction; therefore, Alexa can address this limitation. Alexa can reach all students (Moussalli & Cardoso, 2019); having a few or more Alexas in the classroom may enable many input and output interactions. The interlocutor is engaged with Alexa in an interaction, and for the interlocutor to interact, he/she must also produce output. Through successful negotiations with Alexa, learners should be able to understand crucial information about their utterances— for example, whether their vocabulary output matches up with context (Dizon, 2017).

Another characteristic of the interactive hypothesis is that when the learners have time to stop and clarify meaning, they can understand and comprehend it better. With Alexa, it is the learners' choice to continue their interactions by calling Alexa by her name.

The Natural Approach and IPA

Different characteristics from the natural approach to language acquisition also justify using Alexa to develop the English language. An essential factor in the natural approach is comprehensible input. According to this approach, the input is language input that listeners can understand despite needing to understand all its words and structures. This is an essential feature of Alexa, similar to the natural processing of language acquisition; as such, the learner might be able to acquire fluent, correct speech naturally and apply it to speech unconsciously; "IPAs can motivate students

to practice their newly acquired oral skills and try their learning hypotheses—e.g. via IPAs built-in speech recognizer” (Moussalli & Cardoso, 2019, p. 2).

According to the affective filter, however, there might be the danger of anxiety or fear of communicating with Alexa, and this might lead to a block in acquiring the language (Krashen & Terrell, 1983); when the affective filter is lowered by creating a learning environment where the students are motivated and feel safe, there is a better chance for language learning; studies show that many times learners will have positive perceptions towards the use of IPA in language acquisition contexts (Dizon, 2017; Underwood, 2017). At times, the interaction with an IPA might be less intimidating than peer interaction or interactions with the teacher.

The Acquisition Versus Learning Hypothesis and IPA

According to Krashen’s acquisition versus learning hypothesis (1982), acquisition of a language and learning a language are two different things. Acquisition is the subconscious process, while learning is conscious. In continuation to Krashen’s theory, language acquisition usually occurs in an informal environment, while learning occurs in a more formal one (Krashen, 1982; Krashen & Seliger, 1976).

Alexa, as an artificial intelligence, can serve as both. Alexa can be an intelligent learning tool that can assist the learner in learning the material taught in the class; however, she can also be used for acquisition out of class. Is it possible that acquisition and learning will co-occur in the class by interacting with Alexa? According to Krashen (Krashen, 1982; Krashen & Seliger, 1976), acquisition occurs when attention is focused on meaning rather than language form. Alexa does not only deal with the conscious aspect of language learning, but interactions with Alexa might also lead to a subconscious process of language acquisition by focusing on communication rather than only on form-focused language teaching.

Information Processing Theory and IPA

Information processing (IP) theory focuses on mental processes when learning a language. According to this theory, the human brain is similar to a computer; that is, the brain requires processing to learn, just like the computer processes learning (McLaughlin et al., 1983). McLaughlin states that learning in L2 involves moving from controlled to automatic processing by practising (1983). Conscious processing takes much effort both on the individual cognitive skills and on the short-term memory; only when it becomes automatic will it make room for new structures; that is, the information in the short-term memory will move from the short-term memory to the long-term memory, allowing for new information space.

This theory suggests that the input that the learners receive needs to be engaging in order to become intake (the input that learners notice and pay attention to); “speaking to AI (artificial intelligence) assistants was considered highly engaging

by all students” (Underwood, 2017). In addition, the learning must enable to move from the controlled to the automatic, from short-term memory to long-term memory; this is done according to McLaughlin (1983) by practising, “Alexa can provide language learners with meaningful opportunities to practice the target language productively” (Dizon, 2017, p. 54). This way, the process from the conscious to the automatic level will most likely occur.

Teaching/Learning Approaches and IPA

Further support for using Alexa in the EFL classroom comes from the teaching/learning approaches and methods. Many teaching/learning approaches justify using IPA in the classroom, such as adaptive learning, personalization, differentiation, and the coteaching approach.

Adaptive Learning, Personalization, Differentiation, and IPA

According to Tomlinson and Imbeau (2010), differentiated instruction caters to instruction to meet individual needs. The differentiation method modifies four elements: content, process, product, and affect (Tomlinson, 2008). Tomlinson (2008) suggests that this modification becomes possible by noticing the student needs, such as the student’s readiness, interests, and learning profile. Using Alexa in the classroom can be a unique way to account for such needs.

Being an IPA, Alexa can identify each student by his/her profile and cater to the student’s readiness level and interests. For example, suppose a student needs Alexa to talk slowly. In that case, Alexa, an artificial intelligent assistant, will be able to identify this need after a few interactions and talk more slowly when interacting with that student. In fact, according to research, adaptive learning, personalization, and learning style are important concepts that relate to A.L. (Banger, 2019). All of these have the same purpose: to address the unique needs of each learner. “Rather than adopting a ‘one size fits all’ approach, the use of AI education allows for tailored learning by positioning the learners at the centre of the learning environments” (Banger, 2019, p. 231).

The Coteaching Approach and IPA

The coteaching model is innovative and leading, like the expression “two are better than one” (Ecclesiastes 4:9–12). The question arises as to whether coteaching only applies to humans working side by side in different models or whether it can be attributed to a future-oriented pedagogy that extends the model to artificial

intelligence. This model of co-instruction is essential in teaching English as a foreign language because of the gaps and differences among students. In this teaching-learning model, Alexa can function as a coteacher who invites and mediates translation definitions, asks questions, reads a story, and allows for differential and personal responses in a heterogeneous classroom.

AI as a Motivational Tool in Second Language Learning

Motivation has long been recognized as crucial in second language learning, driving learners' progress, and shaping their language acquisition journey. With the emergence of artificial intelligence (AI), there is now an innovative tool that holds the potential to enhance and amplify motivation among language learners. This section explores how AI can be integrated into the historical classifications of motivational second language learning theories, shedding light on its role in fostering motivation and transforming language education.

Motivation in second language learning has been a significant area of research for many decades, recognized as a phenomenon that acts as a primary catalyst and a crucial driving force throughout the learning process (Takac & Berka, 2014). With the advent of artificial intelligence (AI), we have a powerful tool that can enhance and amplify motivation in language learners. Let us explore how AI can be integrated into the different historical classifications of motivational second language learning theories.

During the social-psychological period of motivation, which emphasizes the role of the social environment, AI can provide valuable support. By leveraging AI, learners can engage in social contexts and interactions outside the traditional classroom setting. Virtual language exchange programs, language learning chatbots, and AI-powered language learning communities create opportunities for learners to practice their target language with native speakers, receive feedback, and build meaningful connections. AI facilitates integrative and instrumental motivation by offering a platform for authentic communication and practical language use (Csizér & Dörnyei, 2005; Ushioda, 2012).

Moving on to the cognitive-situated period, where learners' mental processes influence their motivation, AI can play a pivotal role in creating engaging and personalized learning experiences. Adaptive learning platforms powered by AI algorithms can analyse learners' strengths, weaknesses, and preferences, tailoring the content and activities to their needs. Adaptive AI systems boost learners' intrinsic motivation and self-determination by providing immediate feedback. Additionally, AI can offer gamified language learning applications, virtual reality simulations, and interactive language exercises to enhance cognitive engagement and stimulate motivation (Takac & Berka, 2014; Deci & Ryan, 1985).

Within the process-oriented period, which explores the changes in individuals' motivation as they learn a second language, AI can contribute by tracking and visualizing learners' progress. AI-powered learning platforms can generate

comprehensive progress reports, highlighting achievements, identifying areas for improvement, and setting achievable goals. By providing a clear sense of progression, AI instills a sense of accomplishment and fosters long-term motivation. Furthermore, AI can offer personalized study plans, adaptive content sequencing, and intelligent reminders, ensuring learners stay motivated and committed to their language learning journey (Dörnyei & Ottó, 1998; Dörnyei, 2009).

In the socio-dynamic period, which focuses on the dynamic nature of motivation and language learning, AI can serve as a dynamic companion. Chatbots and virtual language tutors driven by AI can engage learners in realistic conversations, adapting their language use and complexity based on learners' proficiency levels. These AI-driven interactions provide a dynamic and responsive learning environment, where learners feel supported and motivated to continue practicing and improving their language skills. Moreover, AI can analyse learners' linguistic patterns, identify areas of linguistic growth, and provide targeted feedback to enhance their motivation and performance (Dörnyei & Ushioda, 2009).

By embracing AI as a motivational tool in second language learning, we can tap into its potential to revolutionize how we approach language acquisition. From facilitating social interactions to personalizing learning experiences, tracking progress, and providing dynamic support, AI empowers learners and strengthens their motivation throughout their language learning journey. As technology advances, the integration of AI in language education promises to unlock new possibilities and inspire learners to achieve their language learning goals.

The Impact of AI on Student Motivation, Confidence, Engagement, and Language Learning Outcomes

In recent years, the influence of artificial intelligence (AI) on various aspects of education, including language learning, has been the subject of extensive research. Few studies have explored the impact of AI on student motivation, confidence, engagement, and language learning outcomes, with promising findings. This chapter delves into the existing literature to examine the effects of AI in second language learning and its implications for learners.

Several studies have investigated the impact of AI on motivation in second language learning and have reported positive findings. Haristiani and Rifai (2021) employed a comparable survey-based method using AI, examining the perspectives of L2 Japanese learners in Indonesia regarding an interactive grammar chatbot. Students indicated heightened motivation, increased practice durations, and improved self-assessed grammar levels. Previous studies involving IPAs have found that F.L. learners generally have positive perceptions of their use in language learning. For instance, Tai and Chen (2020) observed that learners believed Google Assistant made L2 interaction more motivating and enjoyable, which aligns closely with the results of Moussalli and Cardoso (2016) and Dizon (2017).

Dizon (2020) employed Davis' (1989) technology acceptance model (TAM) and found that university students held positive attitudes towards Alexa for in-class F.L. learning. In the context of out-of-class, self-directed L2 learning, participants learning English as a foreign language (EFL) in Dizon and Tang (2020) they were perceived Alexa to be advantageous for autonomous F.L. learning. Another area that has attracted research attention is L2 learners' patterns of interaction when communicating with IPAs. In Moussalli and Cardoso (2020), researchers discovered that L2 learners most frequently resorted to repeating the same request when faced with communication difficulties, which aligns with the findings of Chen et al. (2020). In contrast, abandonment was the most popular strategy Dizon and Tang (2020) used to overcome a communication breakdown. There is a substantial body of literature on expressed enthusiasm in classroom settings (Keller et al., 2014), indicating positive impacts on learners' emotional states (Kunter et al., 2011), interest and intrinsic motivation (Keller et al., 2014; Kim & Schallert, 2014), attention and learning achievement (Kunter et al., 2011). Applied to multimedia learning environments, enthusiastic human voices can enhance learning outcomes, emotional states, and perceived speaker's social and persona ratings (Lawson et al., 2021; Liew et al., 2020).

The Diffusion of Innovation Theory

The diffusion of innovation theory offers a comprehensive framework for understanding how AI-assisted language learning tools like Alexa are adopted within educational settings (Rogers & Williams, 1983). It categorizes adopters into innovators, early adopters, early majority, late majority, and laggards, each with distinct characteristics and motivations. Innovators and early adopters may be the first to experiment with Alexa, drawn by its novelty and potential benefits. The early majority may require evidence of effectiveness before adopting, while the late majority and laggards may be more cautious and resistant. Effective communication and support channels, driven by educators and institutions, are essential in accelerating the diffusion process.

By incorporating the diffusion of innovation theory, educators and policymakers can gain insights into the dynamics of AI adoption in language education, addressing the needs and concerns of various adopter groups and ultimately enhancing language learning outcomes.

Methodology

This chapter presents the methodology employed in the study, including the research approach, participant selection, data collection methods, and data analysis techniques.

Research Approach

The study adopted a qualitative research approach to explore the experiences of EFL students who used Alexa during their English lessons. Qualitative research is well-suited for in-depth investigation of participants' perceptions, attitudes, and experiences, providing valuable insights into the phenomenon under study.

Sample

The participants in this study were EFL college students who had experience using Alexa as an AI assistant during their English language learning. A purposive sampling technique was employed to select participants who met the criteria of having used Alexa during their English lessons. The sample size consisted of 60 participants, ranging in age from 18 to 25 years and representing various proficiency levels in English.

Data Collection Methods

Data were collected through semi-structured interviews, allowing flexibility and depth in exploring participants' experiences with Alexa. The interview questions were designed to elicit information regarding participants' experiences with Alexa, its impact on their motivation to learn English, and the benefits they perceived from using the AI assistant. The interviews were conducted in a comfortable and private setting, ensuring a conducive environment for open and honest responses.

These sample questions were designed to explore the different themes related to the experiences, motivation, confidence, engagement, and perceived benefits of using Alexa during English lessons.

These sample questions were designed to explore the different themes related to the experiences, motivation, confidence, engagement, and perceived benefits of using Alexa during English lessons. The selection of themes for the thematic analysis in this study was grounded in a comprehensive review of existing literature and theories related to language learning and the integration of AI technology. The predetermined themes were not arbitrary but derived from established concepts and frameworks widely recognized and discussed within the field. This section provides a rationale for selecting these specific themes, emphasizing their relevance to the broader body of literature. While the initial coding approach was deductive and based on predetermined themes derived from existing literature and theories, we also recognized the importance of remaining open to the possibility of unexpected themes emerging during the data analysis process. This deliberate openness to unexpected themes reflects our commitment to a comprehensive and flexible

analysis approach. We aimed to ensure that our data analysis was open to predefined thematic categories but remained receptive to unanticipated findings. This approach allowed us to capture the full richness and complexity of participants' experiences and perspectives.

Results

The collected data were analysed using thematic analysis, a widely used qualitative analysis technique. Thematic analysis involves identifying, analysing, and reporting patterns or themes within the data. The analysis began with familiarising the data through repeated readings of the interview transcripts. Next, initial codes were generated to capture meaningful units of information. These codes were then organized into potential themes, refined, and reviewed to ensure their coherence and relevance to the research questions. The final themes were then used to interpret the findings and answer the research questions (Table 4.1).

Table 4.1 Interview questions

Themes	Interview questions
Experience with Alexa	Can you describe your overall experience with using Alexa for language learning purposes?
Influence on motivation	How has incorporating technology into your language learning routine influenced your motivation and enthusiasm?
Engagement and interactivity	What aspects of using Alexa make language learning more engaging and interactive?
Support and encouragement	How do you feel supported and encouraged in your language learning journey when using Alexa?
Immediate feedback	Can you share examples of how receiving immediate feedback during language learning activities has helped you improve your skills?
Motivation and consistency	What keeps you motivated and consistently using Alexa as a language learning tool?
Advantages and benefits	From your perspective, what are the main advantages or benefits of incorporating Alexa into your language learning practice?
Alignment with language goals	How does using Alexa align with your personal language learning goals and objectives?
Influence on confidence	Can you describe any instances where using Alexa has positively influenced your confidence in language use?
Unique features of Alexa	What do you think sets Alexa apart from other language-learning tools or methods you have used?

Findings

This chapter presents the findings of the study based on the thematic analysis of the interview data. It provides an in-depth exploration of the themes that emerged from the participants' experiences with Alexa during their English lessons.

Enhanced Motivation

The first central theme from the data was enhancing students' motivation to learn English through coteaching with Alexa. Participants reported feeling more motivated and inspired to engage in language learning when interacting with Alexa. They expressed enthusiasm for the interactive and dynamic nature of the AI assistant, which made their English lessons more enjoyable and engaging. This heightened motivation aligns with the diffusion of innovation theory (Rogers & Williams, 1983), where early adopters and innovators are characterized by enthusiasm for new technologies. These individuals are often driven by the prospect of experiencing improved outcomes and enhanced practices, precisely what the study participants reported. Alexa's dynamic and interactive nature contributed to the heightened motivation, a characteristic highly appealing to early adopters (Table 4.2).

Confidence and Engagement

Participants shared that interacting with Alexa in English significantly increased their confidence levels. They felt more comfortable speaking and practising their English skills with Alexa than in traditional classroom settings. The non-judgmental nature of the AI assistant allowed them to make mistakes without fear of embarrassment, fostering a supportive learning environment. The increased confidence positively impacted their engagement in the learning process, leading to improved language proficiency. This aligns with the diffusion of innovation theory's early adopters and innovators (Rogers & Williams, 1983), who are typically more willing to take risks and explore novel technologies. Early adopters, in particular, exhibit a higher tolerance for ambiguity and are more likely to embrace innovations that offer benefits, such as increased confidence and engagement, as reported by the participants (Table 4.3).

Table 4.2 Sample utterances: enhanced motivation

Participant	Utterance
Q1	“Using Alexa in my English lessons made me more excited about learning. It is like having a conversation with a friend”.
Q2	“Alexa was like a language partner. It made learning English fun, and I always looked forward to the lessons”.
Q3	“I felt motivated to practice my English more because Alexa made it feel like a game. It was challenging but in a good way”.
Q4	“Alexa’s interactive activities made me want to learn more. It was like solving puzzles while improving my English”.
Q5	“I found myself more motivated to study English because of Alexa’s presence. It added a new level of interest and engagement”.
Q6	“Alexa made learning English feel less like a chore. It was exciting to interact with technology and improve my language skills”.
Q7	“Using Alexa in our lessons motivated me to study English outside class. I wanted to explore more and see what else I could learn”.
Q8	“I loved the variety of activities Alexa offered. It kept me engaged and eager to continue practising English”.
Q9	“The gamified approach with Alexa made learning English feel like a fun challenge. It pushed me to improve and achieve better results”.
Q10	“Interacting with Alexa during lessons sparked my curiosity and motivated me to explore more English content independently”.
Q11	“Alexa’s interactive features make learning English enjoyable and motivating. I felt more motivated to practice and improve my skills”.
Q12	“I appreciated that Alexa adapted to my learning needs. It personalized the experience and motivated me to keep going”.
Q13	“Alexa’s presence in our English lessons motivated me to participate actively. It was a refreshing and engaging approach”.
Q14	“Using Alexa helped me develop a sense of achievement and progress in my English learning. It motivated me to set higher goals”.
Q15	“Alexa’s interactive exercises made learning English feel like a game. It motivated me to practice and improve my language skills”.
Q16	“The interactive nature of Alexa’s lessons made learning English more engaging. It motivated me to take an active role in my learning”.
Q17	“With Alexa, I felt a sense of accomplishment whenever I completed a task. It motivated me to continue learning and progressing”.
Q18	“The dynamic and interactive nature of Alexa’s lessons motivated and engaged me. It made learning English enjoyable and fulfilling”.
Q19	“I found myself more motivated to study English when using Alexa. Its interactive and responsive nature made the learning experience enjoyable”.
Q20	“Interacting with Alexa in my English lessons brought a new level of excitement. It motivated me to participate and learn actively”.

Non-judgmental Environment

The participants highly valued the opportunity to practice their English language skills in a non-judgmental environment provided by Alexa. They appreciated the

Table 4.3 Sample utterances: confidence and engagement

Participant	Utterance
Q1	“With Alexa, I felt more confident to speak English out loud. I did not have to worry about making mistakes or being judged”.
Q2	“Alexa encouraged me to participate actively in class. I felt comfortable asking questions and practising my speaking skills”.
Q3	“I noticed that my confidence in speaking English improved. Alexa’s patient and encouraging responses helped me overcome my shyness”.
Q4	“I became more engaged in the lessons when Alexa was present. I felt more comfortable expressing my ideas and opinions in English”.
Q5	“Using Alexa helped me gain confidence in my English pronunciation. I felt more comfortable speaking and being understood”.
Q6	“Alexa provided a safe space for me to practice speaking without fearing judgment. It boosted my confidence and reduced my anxiety”.
Q7	“I felt comfortable experimenting with new vocabulary and expressions with Alexa. It allowed me to be creative without the fear of being corrected”.
Q8	“The non-judgmental environment with Alexa made me more willing to take risks with my English. I learned from my mistakes and became more confident”.
Q9	“Alexa’s positive and encouraging feedback motivated me to keep pushing myself and trying new things in English”.
Q10	“The interactive nature of Alexa’s lessons helped me engage more actively with the language. I felt more connected and invested in my learning”.
Q11	“Using Alexa helped me overcome my fear of speaking English. I gained more confidence and felt more comfortable expressing myself”.
Q12	“Alexa’s supportive and non-critical approach helped me build confidence in my English skills. It encouraged me to take risks and improve”.
Q13	“With Alexa, I felt more empowered to express my opinions in English. It created a comfortable environment that boosted my confidence”.
Q14	“The interactive exercises with Alexa made me feel engaged and involved in learning. It boosted my confidence and motivation”.
Q15	“Interacting with Alexa helped me become more confident in my English abilities. I felt more at ease when communicating in English”.
Q16	“Alexa’s non-judgmental approach allowed me to speak freely without fearing making mistakes. It boosted my confidence and fluency”.
Q17	“I appreciated that Alexa provided positive reinforcement for my efforts in learning English. It boosted my confidence and kept me motivated”.
Q18	“With Alexa, I felt supported in my language learning journey. It boosted my confidence and encouraged me to participate in class actively”.
Q19	“Alexa’s encouragement and positive feedback increased my confidence in speaking English. It made me more willing to take risks and improve”.
Q20	“Using Alexa in my English lessons helped me overcome my fear of speaking in front of others. It built my confidence and improved my fluency”.

absence of human judgment, allowing them to experiment freely with different language structures and expressions. Participants felt that this freedom to explore and learn without the fear of making errors contributed significantly to their language development. Alexa’s perception of a non-judgmental environment resonates with the early adopters and innovators described in the diffusion of innovation theory

(Rogers & Williams, 1983). Early adopters are often characterized by their willingness to experiment and engage with innovations, even in nontraditional ways. In this study, participants appreciated the freedom to explore and experiment with language without fear of judgment. This sentiment aligns with the risk-taking nature of early adopters and innovators (Table 4.4).

Immediate Feedback

Another significant finding was the perceived benefit of receiving immediate feedback from Alexa during English lessons. Participants found the instant feedback provided by the AI assistant valuable in correcting their pronunciation, grammar, and vocabulary usage. The timely feedback helped them identify and rectify their language errors, enhancing their language learning experience. This feature aligns with the expectations of early adopters and innovators (Rogers & Williams, 1983), who seek technologies that offer tangible benefits and enhance their practices. Early adopters are typically more receptive to innovations that provide timely and valuable feedback, facilitating their mastery of the technology. The participants' positive response to Alexa's immediate feedback mirrors the preferences of these early adopter groups (Table 4.5).

Continued Use

The fifth theme from the data was participants' willingness to continue using Alexa for learning English beyond the classroom. Many participants expressed their desire to incorporate Alexa into their self-study routines and use it as a language-learning tool outside of formal English lessons. They recognized the convenience and accessibility of the AI assistant and believed that continued interaction with Alexa would support their ongoing language development. The willingness of participants to continue using Alexa for language learning outside of the classroom highlights the potential for diffusion among the early majority (Rogers & Williams, 1983). Early majority adopters are characterized by their pragmatism and seek technologies that offer clear advantages and can be integrated into their daily routines. Participants recognized the convenience and accessibility of Alexa, indicating its potential appeal to the early majority as a supplementary language learning tool (Table 4.6).

Table 4.4 Sample utterances: non-judgmental environment

Participant	Utterance
Q1	"It was liberating to practice English with Alexa. I did not feel self-conscious about my mistakes, which helped me improve faster".
Q2	"I could try different sentences and expressions without worrying about being corrected. Alexa was patient and just focused on helping me learn".
Q3	"The non-judgmental environment with Alexa made me feel more relaxed during the lessons. I could freely express myself and focus on improving".
Q4	"I felt comfortable exploring different language structures with Alexa. It allowed me to experiment and learn without fearing being judged".
Q5	"The absence of judgment from Alexa made me feel more at ease when practising English. I could make mistakes and learn from them without feeling embarrassed".
Q6	"I appreciated that Alexa did not criticize my mistakes but helped me understand and correct them. It created a supportive learning environment".
Q7	"With Alexa, I did not have to worry about making mistakes. It allowed me to take risks and learn new language skills without feeling judged".
Q8	"The non-judgmental atmosphere with Alexa made me more willing to experiment with different language structures. It boosted my confidence in English".
Q9	"I felt free to express myself authentically with Alexa. I could practice English without the fear of being evaluated or criticized".
Q10	"Using Alexa in my English lessons created a non-threatening environment. I felt more comfortable making mistakes and learning from them".
Q11	"I appreciated that Alexa did not interrupt or correct me immediately when I made mistakes. It allowed me to complete my thoughts and learn from them".
Q12	"The non-judgmental nature of interacting with Alexa helped me focus on my learning without feeling self-conscious. It created a positive learning space".
Q13	"I felt safe practising my English with Alexa. It created a non-judgmental environment where I could improve without fearing criticism".
Q14	"Alexa's non-judgmental approach made learning English feel less intimidating. I could relax and focus on improving without worrying about being corrected".
Q15	"I appreciated that Alexa provided a supportive learning environment. It allowed me to make mistakes, learn from them, and grow without feeling judged".
Q16	"The non-judgmental atmosphere with Alexa made me more willing to take risks in my English learning. I could explore and experiment without hesitation".
Q17	"With Alexa, I did not feel self-conscious about my English proficiency. It allowed me to practice and learn at my own pace without feeling judged".
Q18	"The non-judgmental interaction with Alexa helped me gain confidence in my English abilities. I could freely express myself and receive feedback without judgment".
Q19	"I appreciated that Alexa did not correct every mistake I made. It allowed me to focus on expressing myself and gradually improve my English skills".
Q20	"Using Alexa in my English lessons created a non-judgmental space where I could learn and grow without feeling embarrassed about my language proficiency".

Table 4.5 Sample utterances: immediate feedback

Participant	Utterance
Q1	“One of the immediate benefits of using Alexa was receiving instant feedback on my pronunciation. It helped me correct my mistakes right away”.
Q2	“With Alexa, I did not have to wait for the teacher to provide feedback. I received immediate feedback on my language usage, which helped me improve faster”.
Q3	“Using Alexa provided me with immediate feedback on my speaking skills. It highlighted areas where I needed improvement and allowed me to adjust quickly”.
Q4	“The instant feedback from Alexa was invaluable. It helped me identify my grammar errors and guided me in using the correct language structures”.
Q5	“I appreciated that Alexa immediately pointed out my pronunciation errors. It allowed me to practice and correct my pronunciation in real-time”.
Q6	“One of the benefits of using Alexa was the immediate feedback it provided on my language fluency. It helped me become more aware of my speech patterns”.
Q7	“Using Alexa for language practice meant I didn’t have to wait for the teacher’s feedback. I received immediate corrections, which improved my accuracy”.
Q8	“I found the immediate feedback from Alexa to be extremely helpful. It pointed out my vocabulary mistakes and suggested better word choices”.
Q9	“The instant feedback from Alexa allowed me to address my language weaknesses immediately. It helped me refine my language skills and avoid repeating mistakes”.
Q10	“One of the benefits of using Alexa was the immediate feedback on my listening comprehension. It confirmed whether I understood the spoken language correctly”.
Q11	“With Alexa, I received immediate feedback on my language usage, such as correct verb tenses and sentence structures. It helped me improve my overall accuracy”.
Q12	“The immediate feedback from Alexa helped me identify my weak areas in English. It guided me on where to focus my efforts for improvement”.
Q13	“I appreciated that Alexa provided immediate feedback on my grammar mistakes. It allowed me to learn from those errors and apply the correct grammar rules”.
Q14	“Using Alexa meant that I could receive immediate feedback on my pronunciation. It helped me refine my accent and improve my overall speaking clarity”.
Q15	“One of the benefits of using Alexa was the instant feedback on my language skills. It helped me gauge my progress and make necessary adjustments”.
Q16	“I found the immediate feedback from Alexa on my vocabulary usage extremely useful. It helped me expand my vocabulary and use words more accurately”.
Q17	“With Alexa, I didn’t have to wait for a teacher’s response to my questions. I received immediate feedback, which accelerated my learning process”.
Q18	“I appreciated the instant feedback from Alexa on my language fluency. It helped me identify areas where I needed to improve my pace and smoothness of speech”.
Q19	“The immediate feedback from Alexa helped me correct my language errors immediately. It prevented those mistakes from becoming ingrained in my language usage”.
Q20	“Using Alexa allowed me to receive immediate feedback on my pronunciation. It helped me correct my accent and pronunciation nuances in real-time”.

Table 4.6 Sample utterances: continued use

Participant	Utterance
P1	“After using Alexa in my English lessons, I’m motivated to continue using it outside class. It has become a valuable learning tool for me”.
Q2	“I found Alexa so helpful that I plan to use it even after the course ends. It’s convenient and provides personalized language practice”.
Q3	“Using Alexa for learning English has been so beneficial that I want to integrate it into my daily language learning routine. It’s fun and effective”.
Q4	“Alexa has become a part of my English learning journey. I see its value in providing immediate feedback and personalized practice. I’ll continue using it”.
Q5	“I see the potential of Alexa as a long-term language learning companion. I intend to use it to enhance my English skills beyond the classroom”.
Q6	“Alexa has made learning English more enjoyable for me. I want to continue using it because it’s interactive and helps me progress in my language learning”.
Q7	“The positive impact of using Alexa in my English lessons has motivated me to incorporate it into my self-study routine. It’s a valuable resource for practice”.
Q8	“I’m impressed with how Alexa has enhanced my English learning experience. I’ll continue using it because it’s convenient and offers valuable feedback”.
Q9	“Alexa has proven to be a reliable language learning tool. I see myself using it beyond the classroom to reinforce what I’ve learned and further improve”.
Q10	“The benefits of using Alexa in my English lessons are clear. I’m excited to continue using it as a practice tool and explore its full potential”.
Q11	“Using Alexa has been a game-changer in my English learning journey. I want to continue using it because it provides personalized and engaging practice”.
Q12	“After experiencing the benefits of using Alexa for learning English, I’m committed to using it regularly. It’s a convenient and effective learning companion”.
Q13	“The positive impact of Alexa on my English learning has convinced me to keep using it. It’s an invaluable tool for practice, feedback, and language improvement”.
Q14	“I am grateful for the opportunity to use Alexa in my English lessons. I will continue using it to supplement my learning because it is enjoyable and effective”.
Q15	“Alexa has become an integral part of my English learning process. I am motivated to continue using it for its interactive lessons and immediate feedback”.
Q16	“The benefits I have experienced with Alexa have encouraged me to make it a regular part of my language learning routine. It’s a reliable and engaging tool.”
Q17	“After seeing the positive impact of Alexa on my English skills, I’m committed to using it consistently. It’s a powerful tool that supports my language development”.
Q18	“Using Alexa in my English lessons has opened up new possibilities. I’m excited to continue using it outside class as a language learning resource”.
Q19	“I’m impressed with the capabilities of Alexa in enhancing my English learning. I’ll continue using it because it offers valuable practice and immediate feedback”.
Q20	“The positive experiences with Alexa have motivated me to integrate it into my ongoing language learning efforts. It’s a reliable and effective tool”.

Perceived Benefits

The final theme from the qualitative analysis of the participants' interviews focuses on the perceived benefits of using Alexa during their English lessons. Participants expressed their views on the advantages they experienced while interacting with the AI assistant. This theme shows how Alexa's features and functionalities positively impacted their language learning journey. The final theme, focusing on the perceived benefits of using Alexa, reinforces the notion that the advantages offered by new technologies often drive early adopters and innovators. These adopter groups are more likely to explore and champion innovations that bring tangible benefits to their practices. Participants' positive views on the advantages of Alexa align with the characteristics of early adopters and innovators described in the diffusion of innovation theory (Table 4.7).

Discussion

The findings of this study align with existing research on the benefits of incorporating AI technology, specifically Alexa, in language learning contexts. The themes that emerged from the data—enhanced motivation, increased confidence and engagement, a non-judgmental learning environment, and the value of immediate feedback—provide valuable insights into the experiences of EFL students utilizing Alexa during English lessons.

Enhanced Motivation: Consistent with previous studies (Tali & Chen, 2020; Keller et al., 2014; Kim & Schallert, 2014), our findings indicate that incorporating Alexa in English lessons enhances students' motivation. The interactive and dynamic nature of the AI assistant, resembling conversations with a friend, creates a stimulating and enjoyable learning environment. This aligns with the Self-Determination Theory, which emphasizes the importance of autonomy, competence, and relatedness in fostering intrinsic motivation (Ryan & Deci, 2000). By providing engaging and interactive language learning experiences, Alexa contributes to the student's motivation to actively participate and invest in their learning process.

Increased Confidence and Engagement: The integration of Alexa in language learning promotes increased confidence and engagement, consistent with previous research findings (Nazari et al., 2021). Interacting with Alexa provides a comfortable space for students to practice speaking and improve their language skills without fear of judgment or embarrassment. This non-judgmental environment allows learners to take risks, experiment with language structures, and explore expressions freely. Through repeated interactions and positive experiences (Dizon, 2020), students' confidence in using English is bolstered, leading to greater engagement in the learning process.

Non-Judgmental Learning Environment: Our study highlights the significance of a non-judgmental learning environment facilitated by Alexa. This finding aligns

Table 4.7 Sample utterances: perceived benefits

Participant	Utterance
Q1	“Using Alexa helped me improve my pronunciation and fluency. It provided immediate feedback and helped me refine my speaking skills”.
Q2	“One of the benefits of using Alexa was the personalized language practice it offered. It targeted my specific areas of improvement and helped me progress”.
Q3	“I found that using Alexa made my English lessons more engaging and interactive. It kept me motivated and interested in learning”.
Q4	“The convenience of using Alexa for language practice was a major benefit. I could access it anytime, anywhere, and receive instant feedback on my performance”.
Q5	“With Alexa, I had the opportunity to practice my English conversation skills realistically. It helped me build confidence in real-life communication”.
Q6	“One of the benefits I perceived from using Alexa was the opportunity to expand my vocabulary. It introduced me to new words and expressions in context”.
Q7	“Using Alexa provided immediate feedback on my grammar and language usage. It helped me identify and correct my mistakes more effectively”.
Q8	“I appreciated that Alexa adapted to my learning pace and level. It provided challenging yet achievable practice, which helped me progress in English”.
Q9	“One of the benefits of using Alexa was the ability to practice listening comprehension. It presented me with various listening exercises and improved my understanding”.
Q10	“I found that using Alexa in my English lessons increased my motivation to learn. It made the learning process more enjoyable and rewarding”.
Q11	“Using Alexa allowed me to receive immediate feedback on my language skills. It helped me track my progress and identify areas that needed improvement”.
Q12	“I perceived an improvement in my confidence in using English due to using Alexa. It provided a supportive environment for me to practice and grow”.
Q13	“One of the benefits I experienced with Alexa was the authentic language practice it provided. It simulated real-life situations and helped me develop my communication skills”.
Q14	“Using Alexa helped me develop a more natural and fluent speaking style in English. It allowed me to practice conversational English in a comfortable setting”.
Q15	“I found that using Alexa enhanced my overall language skills. It improved my speaking, listening, and comprehension abilities comprehensively”.
Q16	“One of the benefits of using Alexa was the instant feedback it provided. It helped me identify my strengths and weaknesses and focus on improvement areas”.
Q17	“Using Alexa helped me overcome my fear of speaking in English. It created a supportive environment where I could practice without feeling self-conscious”.
Q18	“I appreciated that using Alexa allowed me to practice English self-paced. It accommodated my individual learning needs and preferences”.
Q19	“One of the benefits I perceived from using Alexa was the increased exposure to authentic English. It helped me become more familiar with idiomatic expressions and colloquial language”.
Q20	“Using Alexa for language practice improved my confidence in using English in real-life situations. It bridged the gap between classroom learning and real-world communication”.

with research on the role of supportive and non-threatening environments in language learning (El Shazly, 2021). Learners appreciate the freedom to make mistakes and experiment with language without fearing being corrected or evaluated. By removing the anxiety associated with errors, Alexa creates an atmosphere that encourages learners to take risks and explore language learning with increased confidence (Belpaeme & Tanaka, 2021). The natural approach to language learning also supports this. In a non-judgmental environment, learners can naturally acquire fluent, correct speech and apply it to speech unconsciously.

Immediate Feedback: The provision of immediate feedback by Alexa during English lessons was perceived as highly beneficial by the participants. This finding is consistent with previous studies demonstrating the value of immediate feedback in language learning (Zhai et al., 2021). Immediate feedback allows learners to promptly correct pronunciation, grammar, and vocabulary usage, addressing errors in real time. This timely feedback helps learners identify and rectify their language errors, enhancing their language learning experience. This finding also supports the interaction hypothesis and natural approach theory, which highlight the significance of comprehensible input in language learning by interaction, negotiation, and authentic learning; by Alexa's immediate feedback, the students learn to negotiate for meaning and to interact with Alexa, similar to a live entity.

Continued Use and Perceived Benefits: The positive experiences reported by the participants using Alexa during English lessons suggest a strong potential for continued use of AI technology in language learning. Previous studies on technology acceptance have shown that when learners perceive technology as valuable and beneficial, they are more likely to adopt and continue using it (Park, 2009). The non-judgmental environment and immediate feedback provided by Alexa contribute to learners' positive perceptions of its benefits, fostering continued engagement and utilization (Papadopoulos et al., 2020).

Implications and Future Directions: The findings of this study have implications for both language educators and developers of AI-assisted language learning tools. Incorporating AI technology, such as Alexa, into language learning environments can be a valuable strategy to enhance motivation, confidence, and engagement. Language educators can leverage AI assistants' benefits to create an interactive and supportive learning environment.

Overall, the findings highlight the positive impact of coteaching with Alexa on students' motivation, confidence, and engagement in learning English. The participants particularly valued the non-judgmental environment and immediate feedback provided by Alexa. Furthermore, the findings indicate a strong willingness among participants to continue using Alexa for independent language learning.

It is important to note that while these findings provide valuable insights, the study has some limitations. The sample size was increased compared to the previous version; however, it may still need to represent the diversity of EFL students. Additionally, the study focused solely on the participants' perspectives without incorporating teacher perspectives or comparing the effectiveness of coteaching with Alexa to other instructional approaches.

Future research could involve more extensive and diverse samples, incorporate multiple data sources, employ comparative studies with different instructional

approaches to address these limitations, and further investigate the potential of AI assistants in language learning.

Overall, this study contributes to understanding the benefits of integrating AI assistants like Alexa in English language learning environments. The findings support that such technology can enhance students' motivation, confidence, and language acquisition experiences.

References

- Banger, G. (2019). Business management learning: Research for the age of transhumanism. In *Handbook of research on learning in the age of transhumanism* (pp. 307–327). IGI Global.
- Belpaeme, T., & Tanaka, F. (2021). Social robots as educators. In *OECD digital education Outlook 2021 pushing the frontiers with artificial intelligence, blockchain and robots: Pushing the frontiers with artificial intelligence, blockchain and robots* (p. 143).
- Chen, H. H.-J., Yang, C. T.-Y., & Lai, K. K.-W. (2020). Investigating college EFL learners' perceptions toward the use of google assistant for foreign language learning. *Interactive Learning Environments*, 1–16. <https://doi.org/10.1080/10494820.2020.1833043> [Taylor & Francis Online] [Web of Science ®], [Google Scholar].
- Csizér, K., & Dörnyei, Z. (2005). The internal structure of language learning motivation and its relationship with language choice and learning effort. *The Modern Language Journal*, 89(1), 19–36.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–339.
- Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Plenum.
- Dizon, G. (2017). Using intelligent personal assistant for second language learning: A case study of Alexa. *TESOL Journal*, 8(4), 811–830.
- Dizon, G., & Tang, D. (2020). Intelligent personal assistants for autonomous second language learning: An investigation of Alexa. *Japan Association for Language Teaching Computer Assisted Language Learning Journal*, 16(2).
- Dizon, G. (2020). Evaluating intelligent personal assistants for L2 listening and speaking development, 16–26.
- Dörnyei, Z., & Ottó, I. (1998). *Motivation in action: A process model of L2 motivation*.
- Dörnyei, Z. (2009). The L2 motivational self system. In *Motivation, language identity and the L2 self* (Vol. 36, Issue 3, pp. 9–11). Palgrave Macmillan.
- Dörnyei, Z., & Ushioda, E. (Eds.). (2009). *Motivation, language identity and the L2 self* (Vol. 36).
- El Shazly, R. (2021). Effects of artificial intelligence on English speaking anxiety and speaking performance: A case study. *Expert Systems*, 38(3), e12667.
- Ghaemi, F., & Salehi, N. (2014). Interaction hypothesis: A comprehensive theory of SLA? *International Journal for Teachers of English*, 4(4), 23–33.
- Haristiani, N., & Rifai, M. M. (2021). Chatbot-based application development and implementation as an autonomous language learning medium. *Indonesian Journal of Science and Technology*, 6(3), 561–576.
- Keller, M. M., Chang, M. L., Becker, E. S., Goetz, T., & Frenzel, A. C. (2014). Teachers' emotional experiences and exhaustion as predictors of emotional labor in the classroom: An experience sampling study. *Frontiers in Psychology*, 5, 1442.
- Kim, T., & Schallert, D. L. (2014). Mediating effects of teacher and peer enthusiasm on students' interest in the college classroom. *Contemporary Educational Psychology*, 39(2), 134–144.
- Krashen, S. D., & Seliger, H. W. (1976). The role of formal and informal environments in second language learning: A pilot study. *Linguistics*, 14(172), 15–22.
- Krashen, S. D. (1982). *Principles and practice in second language acquisition*.

- Krashen, S. D., & Terrell, T. D. (1983). *The natural approach: Language acquisition in the classroom*.
- Kunter, M., Frenzel, A., Nagy, G., Baumert, J., & Pekrun, R. (2011). Teacher enthusiasm: Dimensionality and context specificity. *Contemporary Educational Psychology*, 36(4), 289–301.
- Lawson, A. P., Mayer, R. E., Adamo-Villani, N., Benes, B., Lei, X., & Cheng, J. (2021). Recognizing the emotional state of human and virtual instructors. *Computers in Human Behavior*, 114, 106554.
- Levy, M. (1997). *Computer-assisted language learning: Context and conceptualization*. Oxford University Press.
- Liew, T. W., Tan, S. M., Tan, T. M., & Kew, S. N. (2020). Does speaker's voice enthusiasm affect social cue, cognitive load and transfer in multimedia learning?. *Information and Learning Sciences*, 121(3/4), 117–135.
- Lightbown, P. M. (2000). Anniversary article. Classroom SLA research and second language teaching. *Applied Linguistics*, 21(4), 431–462.
- Long, M. H. (1981). Input, interaction, and second-language acquisition. *Annals of the New York Academy of Sciences*, 379(1), 259–278.
- McLaughlin, B., Rossman, T., & McLeod, B. (1983). Second language learning: An information-processing perspective 1. *Language Learning*, 33(2), 135–158.
- Moussalli, S., & Cardoso, W. (2016). Are commercial 'personal robots' ready for language learning? Focus on second language speech. In *CALL communities and culture—short papers from EUROCALL* (pp. 325–329).
- Moussalli, S., & Cardoso, W. (2019). Intelligent personal assistants: Can they understand and be understood by accented L2 learners? *Computer Assisted Language Learning*, 33(1), 1–26.
- Moussalli, S., & Cardoso, W. (2020). Intelligent personal assistants: Can they understand and be understood by accented L2 learners? *Computer Assisted Language Learning*, 33(8), 865–890.
- Nazari, N., Shabbir, M. S., & Setiawan, R. (2021). Application of artificial intelligence powered digital writing assistant in higher education: Randomized controlled trial. *Heliyon*, 7(5), e07014.
- Nunan, D., & Richards, J. C. (2015). *Language learning beyond the classroom*. Routledge.
- Papadopoulos, I., Lazzarino, R., Miah, S., Weaver, T., Thomas, B., & Koulouglioti, C. (2020). A systematic review of the literature regarding socially assistive robots in pre-tertiary education. *Computers & Education*, 155, 103924.
- Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Journal of Educational Technology & Society*, 12(3), 150–162.
- Pavičić Takač, V., & Berka, N. (2014). Motivation in foreign language learning: A look at type of school environment as a contextual variable. *Explorations in English Language and Linguistics*, 2(2), 77–103.
- Rogers, E. M., & Williams, D. (1983). Diffusion of. *Innovations (Glencoe, IL: The Free Press, 1962)*.
- Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary educational psychology*, 25(1), 54–67.
- Schmidt, R., & Frota, S. (1986). Developing basic conversational ability in a second language: A case study of an adult learner of Portuguese. In R. Day (Ed.), *Talking to learn* (pp. 237–326). Newbury House.
- Tai, T. Y., & Chen, H. H. J. (2020). The impact of Google assistant on adolescent EFL learners' willingness to communicate. *Interactive Learning Environments*, 1–18.
- Tomlinson, C. A. (2008). *Goals of differentiation*. Educational leadership.
- Tomlinson, C. A., & Imbeau, M. B. (2010). *Leading and managing a differentiated classroom*. ASCD.
- Underwood, J. (2017). Exploring AI language assistants with primary EFL students. In *CALL in a climate of change: adapting to turbulent global conditions—short papers from EUROCALL* (pp. 317–321).
- Ushioda, E. (2012). Motivation: L2 learning as a special case? In *Psychology for language learning: Insights from research, theory and practice* (pp. 58–73). Palgrave Macmillan.
- Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., et al. (2021). A review of artificial intelligence (AI) in education from 2010 to 2020. *Complexity*, 2021, 1–18.

Chapter 5

Smart Education: Social Risks and Challenges



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Social Challenges and Risks Provoked by Smart Education

The Concept of Smart Education

The term “smart” began to be used in the 1970s in connection with the development of intelligent forces of mass production automation, product design, and enterprise management. The origins of the term smart education are linked to implementing the Malaysian Smart School Implementation Plan project in 1997 (Cheok et al., 2020). At the same time, the idea of creating smart cities was being actively discussed: “The 1997 World Forum on Smart Cities suggested that around 50,000 cities and towns around the world would develop smart initiatives over the next decade” (Hollands, 2008, p. 304).

Over time, the term “smart” has become very widespread. As Michal Klichowski et al. (2015) note, «The Smart’ label is used indiscriminately wherever and whenever something has been technologically enhanced, or a product has been adapted to human needs through some technological solution or even when a new version of a product is developed with some (minor) technological improvement» (p. 1). However, the concept of smart education still does not have a clear, universally accepted definition.

Interpretations of this concept borrowed all the approaches developed to understand the term Smart City (Hollands, 2008). On the one hand, this is the use of the

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term smart education as a label for promotion in the market of educational services. On the other hand, smart education appears as an environment for implementing and integrating smart technologies in the educational process.

Smart education's introduction peaked after Covid 2019 when the whole world was simultaneously forced to switch to remote forms of communication. By this time, the educational systems of various countries had already had computer software, interactive whiteboards, Internet access, distance education experience, etc. (Akhmadov et al., 2023; Černý, 2020). However, the classic system of offline education remained dominant. After the pandemic, education systems switched to hybrid forms of combining online and offline learning (Giacosa, 2023).

One of *the conceptual challenges* of understanding the ongoing changes was the content of the concept of smart education. Some terminological disagreements have arisen within the scientific community. The terms are used simultaneously in scientific turnover:

Smart Learning: Teaching and learning with smartphones and tablets in post-compulsory education is as much about innovation in education as it is about a world in which personal technologies are changing teaching and learning. (Middleton, 2015, p. 1)

Smart education is an association of educational institutions and teaching staff to carry out joint educational activities on the Internet based on common standards, agreements and technologies. (Tikhomirov, 2011, p. 24)

Even though many scientists use these terms, they have yet to have a universal interpretation. Moreover, the terms distance education and smart education are often used synonymously. However, the terms have one thing in common: they are related to the digitalization process of the educational space. The digitalization of education covers a wide range of changes – from technical innovations to the revision of pedagogical approaches. Such a somewhat vague picture of the conceptual apparatus indicates that the abrupt transition of the education system to the online space has led the institution of education into a stressful state when the usual guidelines are lost and a feeling of panic arises. Trying to absorb the shock, students, academic staff, and administration embarked on a fast experimentation and learning process on teaching, learning, and administering digital education (Crawford et al., 2020).

In searching for an explanation of the essence of smart education, scientists based on the fact that the term smart education comes from the meaning of the words “smart” and “intelligent” and has several components: education based on intellect with integration of intelligent information technologies, artificial intelligence technologies, and predictive analytics; mastering competencies within professional activities for full implementation of the follow-up activities in conditions of digital transformation.

The answer to the conceptual challenge of defining a conceptual apparatus is a network methodology. The theoretical basis of network methodology is provided by concepts related to the understanding of network communication in the works of Barnes (1954), Castells (2000), and Bresler (2014). Introducing the term “social networks” as early as 1954, Barnes noted that “The points of this system are people, and the lines of connection between these points indicate how people interact with

each other” (Barnes, 1954, p. 43). Later, Bresler (2014) introduced the term “node” as a structural unit of a social network. A characteristic feature of social networks in online communities is that social networks are dynamic. At any moment, “each node can potentially acquire the status of the central node of the network – the communication centre of the network community for a minimum period, if its information richness is increased compared to other nodes in the network” (Bresler, 2014, p. 47). Castells (2000), discussing the network society, emphasizes symbolic communication as a necessary tool for the creation of culture, where “the hypertext is the vehicle of communication, thus the provider of shared cultural codes” (p. 21).

Thus, network methodology in education implies:

1. **Availability of social networks.** The modern man is on a multitude of social networks at the same time. He is constantly switching from one network to another. Each network exists and develops by increasing the number of members. Therefore, meeting the demands of network community members to involve them in the network comes first in education. On the one hand, a hypertext educational space is formed, the symbolic codes of which should be universal for all social network nodes. Nevertheless, on the other hand, «culture is unified in the hypertext but interpreted individually (in line with the ‘interactive audience’ school of thought in media theory)» (Castells, 2000, p. 21). Alternative educational formats are emerging that «are reflected, amplified, and codified by the fragmentation of meaning in the broken mirror of the electronic hypertext – where the only shared meaning is the meaning of sharing the network» (Castells, 2000, p. 22).
2. **Personalization of education in network methodology** is an individual’s involvement in the information flows of educational hypertext. In this case, “This growing enclosure of communication in the space of a flexible, interactive, electronic hypertext” (Castells, 2000, p. 13) entails simplified methods of presenting information, assessing knowledge, and selective fragmentation of knowledge flows. The issues of a harmoniously developed personality, which are related to the individualization of learning processes, go into the algorithm of managing a specific network “node”, including an individual or a group of individuals. At the same time, the completeness of realization of the individual approach depends on the formed symbolic culture of a particular node.
3. **Availability of a network schedule** (network model). A **network schedule** shows the interdependence of the activities that make up some projects (Plaksin, 2017). The network model is based on algorithms of activity of network actors, network organizers and developers, variants of tasks, projects, etc. This requires creating software that encompasses the entire educational and learning process. For this, it is necessary to create software that covers the entire educational and learning process. The first step is to highlight the content that interests a potential network member to build an educational roadmap for a learner in an educational network system. In the second step, a database is collected from which the individual characteristics of the involved network member can be identified while performing certain activities. In the third step, corrective content, so to speak, begins to

be developed. In remedial content, the emphasis depends on the network member's identified weaknesses and/or strengths. Unlike face-to-face education (offline), the principles of interpersonal contact are changing in network communication (online). Therefore, for each separately identified case, it is necessary to create its algorithm of tasks. A cloud of unifying interests is formed through the network members, where these tasks can move from an individual form of activity to a group form of project creation. Since, as mentioned above, the network works using hypertext space level association, each "node" has its own symbolic code set, so the selection of the student development roadmap is made by focusing on the student's specific interests. Thus, there is no multilateral development of the personality but a concentration on developing its abilities.

Transformation of the Educational System

Changing the Education Landscape

Analysis of traditional educational systems in various countries shows that it is a multilevel system consisting of primary education, secondary education, professional courses, technical schools, institutes of higher education, and universities. All of these levels correlate with specific age characteristics of students. Differences in the age limits of each level of education range from 1 to 2 or 3 years, depending on the country. The lifelong learning (LLL) program has expanded the boundaries and forms of professional education for adults. This program has no age restrictions. However, LLL programs were implemented within the traditional educational landscape: the educational system, consisting of a set of multilevel educational institutions, and social education, where the process of primary and secondary socialization takes place (family, friends, work, etc.).

Distance education paved the way for the evolution of smart education. The use of the Internet has begun to change the educational landscape. In addition to traditional formats, non-formal educational structures that are not strictly educational organizations are emerging. Besides the Internet (Open Big Data, Digital Library, ResearchGate, Google Scholars...), virtual forms of alternative education (Blog, Twitter, Facebook...) are added. This creates a hybrid educational space. Thanks to the Internet, a unified educational cloud is created, filled with resources, databases, and information. The latest intelligent technologies make it possible to create augmented educational reality and virtual educational reality, which significantly expands the real space and increases the possibilities of access to knowledge (Sharonova & Avdeeva, 2019).

The formation of the section on non-formal education is associated with overcoming the school university space, which is limited by legislative norms of different levels (municipal, state, and international law). In China, for example, such

education is called “shadow education”. It includes internationally oriented schools that use educational approaches beyond exam-oriented learning (Liu et al., 2022). As noted by Turkish scientists Yusuf Alpaydin and Cihad Demirli (2022):

today’s schools have started to open up beyond their walls, collaborating with other schools and even international networks. In addition, scientific organizations, universities, nongovernmental organizations, and technology companies are among the institutions that schools cooperate with within the framework of the new education concept. This situation can be seen as the first stage of schools and education overcoming space constraints. (p. 153)

Back in 1970, Ivan Illich, speaking about **the Deschooling Society**, predicted the formation of a new educational network accessible to the general public and providing vast and equal opportunities for learning and teaching (Illich, 1971). The introduction of the Internet into the educational space has made it possible to expand the geographical, temporal, and boundaries of familiar reality through augmented and virtual realities. According to Jackson (2019), the digital learning space allows universities to transcend physical and institutional boundaries and engage with society.

The *challenge* of this transformation of the educational system is that the system itself is disappearing. The blurring of the boundaries of traditional educational systems leads to networked, nonlinear structures that function outside of place, outside of time, and outside of the culture of habitat. Neither the education system nor the digitalizing society was prepared for such a scenario.

The education system is always geared to the needs of society. By now, it is clear to everyone that the new educational system development round, launched by the pandemic, is not a temporary measure. The digitalization of society requires significant changes in education. However, the pandemic violated the logic of progressive action; it demanded decisive revolutionary breakthroughs all at once.

The rapid development of intelligent technologies is a precursor to a new social formation. Thus, destroying the usual boundaries, the education system begins to adjust to future needs, the ideals of which need to be clarified, and it is impossible to build strategic educational goals. The conservative institution of education, which has always relied on time-honoured practices and knowledge, is placed in the unconventional position of becoming the flagship of innovative processes in society. Naturally, the consequence of such a rapid transformation is the emergence of many risks, which will be discussed below.

Changing the Logic of Educational Programs

The Internet, with its potential for information overload, blocks and rejects the linear, progressive logic of the educational program (Kiel & Elliott, 1996; Krezhevskyikh, 2020).

Information chaos prefers to interact with the nonlinear logic of knowledge assimilation. It is believed that fragmented or clipped thinking is a mosaic set of different kinds of information, which does not create a coherent view of the object

phenomenon. However, fragmentary thinking can be seen as the ability to divide the whole into fragments in order to be able to study these fragments more thoroughly and subsequently not just reassemble the original whole but to create a new version of that whole (Semenovskikh, 2014).

In the nonlinear logic of knowledge assimilation, which relies on advances in modern technology in artificial intelligence, it is difficult to say its basis. Gadgets can write by converting voice information. Today's students prefer using voice messages when using search sites or communicating via gadgets rather than typing. Gadgets can count, so it becomes useless to learn the multiplication table. Thus, the ability to read and mastery of high-tech devices remain the fundamentals of knowledge (Pozdeeva, 2016; Bosova & Pavlov, 2019).

In the nonlinear construction of the educational space, the discipline is seen as a fragment of knowledge that appears as an interdisciplinary cloud (Lobanov et al., 2014).

The main problem in building an educational program in smart education is that the end product of education – the smart learner – needs to be defined. Representatives of the Organization for Economic Cooperation and Development (OECD) have put forward 12 critical skills expected to be in demand in the twenty-first century. These skills have been grouped into four main categories: ways of thinking, tools for work, ways of working, and ways of living in the world (Ananiadou & Claro, 2009). The problem is that educational and professional relationships are deformed, and the requirements for teaching a person with a well-rounded, which Rogers spoke about (1951), fully functioning integrity are reduced when integrating intellectual technology into the educational process.

For creating educational strategies (roadmaps) for the student, the logic of building an educational program adjusts to the student's interest, thereby initiating his self-development. Intelligent technology is designed to assist the student and the teacher in learning. AI as intelligent agents should deliver socially shared regulation of learning (SSRL) support through the automation of tasks and provide scaffolding for productive reflection (Järvelä et al., 2020). However, there is a *risk* that students, fascinated by the exploitation of new technologies, will switch their attention and interest not to educational tasks but to using these technologies.

Nonlinear construction of the interdisciplinary space of the educational program involves joint work of students and project activities. However, there are certain *risks* in the joint work of students: there is always a percentage of group members who try to attach themselves to the achievements of others, to hide behind the shoulders of others; performance by each member of a group of separate tasks in joint work does not create for them a complete picture of knowledge which the task was directed at.

In addition, the student forms his learning trajectory, following his interest. Freedom of choice allows him to switch from one subject to another. This attention-shifting process can lead to a situation where long-term attention is not developed, which means that fragments of different pieces of information are stored in memory but are not being analysed as a whole picture of information, with the new

information synthesised and new knowledge being constructed. This may endanger metacognitive development (Daniela, 2018).

Scientists consider project activities as one of the positive components of educational programs. Students learn in-depth and actively by researching and discovering information independently. Because students will need different field knowledge as required by a project's topic during research, they gain interdisciplinary knowledge-based learning experience. While gaining individual and teamwork experience, project-based learning also establishes a relationship with the real-life equivalent of school knowledge (Alpaydın, 2022). However, project activity also has some *risks*. Project activities are more of a scientific and cognitive activity. However, despite all the formal similarities of situations in the educational and cognitive processes when using smart technologies, we should not forget that the goals of the cognitive (scientific-cognitive) and educational processes are not identical (Ardashkin, 2021). According to Ardashkin et al. (2021), "the transformation of the educational situation into an epistemological one can be naive and dangerous, leading the students into a specific delusion, making them believe that their abilities can bring results that they are not ready to achieve" (p. 28).

Changing Pedagogical Methods

As university work demonstrated during the pandemic, the brunt of the transition to online learning fell on the shoulders of faculty. First and foremost, they were required to be proficient users not only of the expected standard set of computer programs but also to be able to master new software resources for the development of new pedagogical methods of teaching in augmented and virtual realities. The continuity of classical pedagogical methods in digitalizing the educational process has also become one of the acute areas of pedagogical tension. In this regard, scientific publications have reflected these problems in the form of criticisms of the detrimental effects of digitalization, among which special attention is paid to educational technology and academic resistance (Jameson, 2019; Bayne, 2015; Woodcock, 2018; Selwyn, 2021).

The difficulty of mastering new technologies undoubtedly creates psychological discomfort for teachers of the older generation. However, these difficulties are solvable and do not provoke some pedagogical collapse. However, the *challenge* for pedagogical practice has been substituting the concept of individualization of learning for the concept of personalization of learning. The educator needs to understand the pedagogical goals. In the classical pedagogy of the late nineteenth and throughout the twentieth centuries, the entire methodological arsenal was aimed at forming a harmoniously developed personality; the founder of these was Comenius (1967). In the twentieth century, under the influence of the ideas of humanistic psychology of Rogers (1951), pedagogical practice began to focus on the individual activity of the learner, the space of self-realization of the personality, as well as the discovery and development of its potential (Terry, 2016). To achieve this goal, an

individualized approach to working with students was developed in the pedagogical environment. According to Unt (1990), the concept of individualisation implies differentiation of learning, the creation of a system of tasks with complex and voluminous material, and the development of a system of training activities, where the individual characteristics of each student are considered.

The key word for understanding these pedagogical efforts is individual learner characteristics. Such individual characteristics include strengths and weaknesses of the student's personality, features associated with the age of students, and the level of psychological readiness for learning activities.

Personalized learning arose from integrating intelligent technology into the educational process. Walkington and Bernacki (2020) analysed different approaches to understanding the phenomenon of personalizing learning and concluded that scientists had focused on technological tools for organizing the learning process. The basis for solving design tasks in developing educational technologies is not the student's characteristics but the interests of a particular user of the educational network.

In this case, the student becomes a network node, which, on the one hand, acts as a faceless person and, on the other hand, forms around itself a specific network built based on self-referral of interests. Individual and psychological features of the student's personality recede into the pedagogical attention background. All efforts are aimed at encouraging personal self-development.

One of the *risks* of personalized learning is the danger of self-identity problems. As noted by Koneva and Lisenkova (2019): "In virtual space, most social characteristics such as gender, age, professional status, marital status, nationality or religious affiliation cease to apply" (p. 16). Among the most important functions of social identity, scientists note the realization of the basic need of the individual to be a member of a particular group, where he will feel safe, while at the same time influencing and evaluating others for self-realization and self-expression (Yadov, 2000). As the virtual network expands the boundaries of identity, a person follows his interests; he begins to lose the essence of individual identity, consisting of characteristics that give a person the quality of uniqueness. From the point of view of psychology, interest refers to the motivational component of personality. It has its subject and a pronounced desire to achieve the goal. However, the realization of interest always takes place in the context of a particular sociocultural environment. In offline communication, the sociocultural environment, in which an individual's interests are realized, is relatively constant and stable. In relating oneself to others, one finds moral and ethical "crutches" for one's actions and thus for one's interests. Following one's interests in the circle of the nascent network of the Internet community and given that the virtual network expands the boundaries of identity, a person is already faced with a variety of sociocultural contexts. In this case, there is a risk of eroding the student's self-identity value foundations. This undoubtedly leads to social zones of tension in the real learning process and requires the search for pedagogical approaches to solving these kinds of problems.

The next challenge of smart education is the need to develop specific pedagogical methods using advanced intelligent technology; that is, we are discussing creating an innovative pedagogy. Since smart pedagogy is based on personalising

learning, the entire didactic arsenal should be student-centred and use the principle of targeting. In recent years, educational technologies, such as augmented reality, computer vision, speech recognition, analytics, etc., have been created to enhance student learning, considering personality traits and adherence to different learning styles, cognitive styles, etc. (Zhu et al., 2016).

The risk of implementing such a targeted approach is the effect of total surveillance of each student, which is based on the paradox of personalization and privacy when dealing with personal data. The personal safety of the student comes to the fore. The collected personal database of the student is so diverse; as we can see from the listed existing technologies, it is not limited to formal data: place of residence, age, and gender. Therefore, personal safety concerns not only the ability to eliminate or minimize economic, and financial losses but also to prevent the *risk* of bullying, a student's involvement in illegal activities, dubious pseudo-religious sects, etc.

Another *challenge* for smart education is replacing knowledge with information. For example, computer technology creates databases, often called knowledge bases, where information is stored, encoded, and transmitted. Moreover, the Cambridge dictionary uses the term information to define knowledge: “understanding of or information about a subject that you get by experience or study, either known by one person or by people generally”; “awareness, understanding, or information that has been obtained by experience or study, and that is either in a person's mind or possessed by people generally”; and “skill in, understanding of, or information about something, which a person gets by experience or study” (Cambridge Dictionary, 2023). However, the two concepts have a clear distinction. Burkhard (2005), analysing the concepts of data, information, and knowledge, builds a logical chain of their relationships: data are facts, information is interpretation of facts, and knowledge is personified information. Interpretation of facts in the transfer of information is associated with the transfer of ready, already formulated by someone else messages and information about objects and phenomena of the world (Tergan & Keller, 2005).

As for knowledge, it is “the result of the process of cognition of reality, verified by social and historical practice and certified by logic; its adequate reflection in the human mind in the form of ideas, concepts, judgments, theories” (Novikov & Novikov, 2013, p. 39). Accordingly, the main differences between information and knowledge are that information is objective and exists independently of the person, while knowledge is subjective and has a personal nature; information can be transferred, while knowledge cannot be transferred because it is the result of personal experience.

Hence, there is a *risk* of degradation of the scientific potential of society since the student learns to compile texts relying on the collection of information. Deprived of the experience of using analytic-synthetic/transformational and creative thought operations (comprehension/understanding, generalization, construction of own worldview platform), the student is unable to distinguish scientific knowledge as objective, generalizing, based on methodological procedures from nonscientific; accordingly, he cannot create new scientific knowledge for theory development. The smart education networking methodology *lays the groundwork* for rethinking the role of the

educator/teacher. It cannot be said that the proposed roles are so new that they did not exist in traditional pedagogy. However, the main difference is that the teacher ceases to be a primary information source and becomes an intermediary who helps students find this information. Student networking involves the ability to work in a group. Therefore, the joint reconstruction of scientific knowledge or innovation based on a teacher-student or student-student combination becomes the most effective learning process. This allows for the integration of research and the development of specific projects. In analysing the transfer of traditional pedagogical practices to the digital media platform, Hajjar Mohajerzad and Josef Schrader (2022) note that teacher and student actions and roles are described as different from established practices and are often presented as ways to expand or diversify.

Using a targeted, personalized approach in developing related technologies for analysing student activity, discussed earlier, not only makes the educator's job more accessible but also carries additional professional *risks*. The teacher must construct personal roadmaps of the learning process to help students creatively transform the information they find and think critically about it, drawing on additional sources. The sphere of students' interests is no longer strictly tied to the logic of a scientific discipline; it is an interdisciplinary cloud. This means that the teacher is forced to go beyond the academic knowledge of a single discipline that reflects his or her speciality. He must assimilate and revise much more information than in traditional pedagogy. One negative consequence of information overload is "information fatigue syndrome", which manifests in cognitive distortions, memory, and attention disorders.

On the other hand, there is the view that students will constantly need mentoring in a smart education regardless of time, place, and sociocultural environment. Lifelong education and personalized education understandings and practices will cause individuals to need guidance and supervision while making decisions (Longworth, 2003).

The Social Risks of the Digitalization of Society and the Response of the Education System

New Forms of Digital Inequality in Society

Digital inequality or digital divide is a worldwide phenomenon that characterizes the significant difference in opportunities to access information and communication technologies and, accordingly, in the ability of individuals, social groups, and social strata of society to consume services through postal and telecommunications services. It can be represented in countries with a high level of economic development.

Digital inequality is a multicomponent whole, and it can manifest itself in limited access to information and communication technologies, in the unreadiness of

users to work with them, and in the limited capacity of national information and functional resources.

According to Van Dijk (2020), the digital divide is an element (as well as a factor) of social inequality. To explore the multifaceted nature of the digital divide, researchers began to create multidimensional analytical constructs, because of which the concept of the digital divide took on a hierarchical form, describing different types of ICT use based on digital literacy, education level, gender, age, English proficiency, etc. (DiMaggio & Hargittai, 2001; DiMaggio et al., 2004.; Hargittai, 2002; Robinson et al., 2015).

In the network society, digital media have become a significant mechanism of segregation through selection in social interaction; in the production, consumption, and exchange of resources; in the choice of residence, work and study; and in public discourse and the expression of one's civic position (Van Dijk, 2020).

Today, with the high digitalisation rate, the knowledge about new ICTs and how to use them still needs to be increased. Access to and effective use of ICTs is one of the decisive factors in the competitive struggle in the labour market for better offers from employers.

Smart education should alleviate this problem and meet the challenge of a rapidly developing digital society. It should allow all members of society to acquire the necessary knowledge and skills to correctly navigate the new information space and effectively use its opportunities. In this case, the claim that digitalization will provide cheap access to high-quality education has become valid for the masses (Kurzweil, 2005). However, Yusuf Alpaydın and Cihad Demirli (2022) doubt that mass education will provide equality of opportunity when discussing inequality in the educational environment (the presence of elite schools and mass schools). For them, it remains unclear how digital education will contribute to the formation of individual qualities. Building on the work of Bourdieu (1986) and Bernstein (2003), they conclude that social inequality will persist in societies.

The development of biotechnology already allows us to discuss the possibility of new prototypes for society. Consciousness is seen as a specific function found in humans and transferred to some other environment; thus, along with genetic inequalities, the union of man and machine can end social inequalities (Alpaydın et al., 2022). In this case, according to Bodrijar (1998), a man's death as a subject occurs. The digitalization of society using biotechnological advances in smart education leads to the *risk* of the destruction of humanity. Assuming that smart technology is meant to replace humans wherever possible, there is some embodiment of human replacement in cognition. Although this scenario is more perceived as a fantasy area, several scientists are actively discussing this topic (Lektorskij et al., 2016).

However, even if we do not consider such alarmist scenarios, the use of intelligent technology as management of personal learning trajectories can lead to the fact that machines, quickly detecting the consumer logic embedded in them, will begin to form a "one-button man" for themselves when developing tasks (Mitri et al., 2009).

Labour Market

Under the influence of the fourth digital revolution, there are qualitative changes in the labour market. Modern technology undoubtedly contribute to faster economic growth (Hagemann, 2019; Schwab, 2016); increasing productivity and global competitiveness (Avdeeva et al., 2019), enhancing competition in the digital sector, e-commerce, and online business, as well as expanding opportunities to increase added value; improving the welfare and quality of life of the population; and reducing public spending on the social sphere through the spread of telemedicine and online education (Odegov & Pavlova, 2018). At the same time, along with the positive characteristics, scientists note the negative impact of digitalization. First of all, we are talking about technological unemployment. Creating cyber-physical systems that can be placed in any engineering object allows the object to communicate with other objects or people. Adding artificial intelligence to an object allows many services to be performed without human involvement. Thus, positions, such as lawyers, financial analysts, doctors, journalists, accountants, insurance brokers, and librarians, will also be partially or fully automated. Unlike previous industrial revolutions, there are very few new jobs (e.g. 0.5% in the USA), and 47% of workers in the USA are at risk of unemployment (Alpaydın et al., 2022). According to OECD 2018 estimates, 14% of jobs in the European community are at risk of automation, and 32% expect significant changes due to digitalization (Job Creation and Local Economic Development, 2018). The OECD 2020 report notes that the labour force has shrunk in almost 30% of OECD regions over the past decade. Most of those who lost their jobs were specialists with secondary education (Job Creation and Local Economic Development, 2020). Yusuf Alpaydın and Cihad Demirli (2022) confirm the trend that higher education provides access to jobs that can be less automated, while vocational education at the high school level provides more automated jobs. Being a university graduate reduces automation risks by 8.8%, while being a vocational training graduate increases automation risks by 2.5% in OECD countries.

The digital society challenges smart education: education must now not only meet the demands of industry and the economy but also anticipate the emergence of new and disappearance of existing professions, not only create a digital educational space but also monitor the professional conformity of educational programs to the labour market and create practices of staff forecasting, focused on high-tech and knowledge-intensive sectors of the economy. Today, a paradoxical phenomenon occurs in the higher education system: students are taught professions that no longer exist, or the educational program's skills are no longer available in digitalized professions. In 2021, the Ministry of Education of the Russian Federation (2022) was forced to close 23 educational programs of secondary vocational education and make changes to 43 educational standards. In parallel with this decision, within the framework of the National Project Education for the period 2019–2022, 59 advanced professional training centres and more than 3100 modern workshops were created and are functioning, which are provided with advanced technologies for conducting practical training sessions on mastering modern professions and subsequent passing exams in the form of a demonstration exam.

Human Capital: New Characteristics

According to T. Schultz's definition, "Valuable qualities acquired by a person, which appropriate investments can enhance, we call human capital" (Schultz, 1968, p. 78).

One of the peculiarities of the impact of information and communication technologies on human capital is the increasing weight and importance in its structure of knowledge and skills required to exist in a digital environment. Digital literacy is becoming an essential part of human capital. These days, digital competencies and skills that form digital literacy are essential for professionals and everyday life, as the socioeconomic environment requires an employee with relevant knowledge and skills and a consumer. Thus, the intensity and effectiveness of interaction with the digital environment are directly dependent on digital literacy, broadly defined as the ability to safely and effectively use digital tools (Berman, 2017).

Digital competencies are a set of knowledge, skills, and behaviours that facilitate finding, retrieving, storing, and evaluating digital data, interacting in a digital environment through digital tools, and developing informational content (Siddiqui et al., 2018). These competencies in education apply to both teachers and students. As the concept of digital competence did not have a universal interpretation in 2017, the European Commission attempted to establish a European Framework for the Digital Competence of Educators: DigCompEdu (Redecker, 2017). Twenty-two core competencies grouped into six spheres were identified. The purpose of this document was to provide a typical frame of reference for developers of digital competence models at all levels, from national governmental to educational organizations, as well as public or private providers of vocational training.

Another trend characterizing the modern state of human capital is developing its network form. It implies the presence of abilities and competencies of interaction with network structures (power, educational, business structures, etc.), acquiring an integrated distributed form in the networking conditions of interaction processes.

Network human capital can be defined as a set of capitalizable distributed network abilities, skills and competencies of managers, highly skilled workers and the population used for effective interaction via the Internet with network government agencies (e-government structures), network business structures (e-business, innovative firms, offshore programming), network scientific and educational communities (network research groups, digital libraries, online universities), and social networks, which are used for various public goods, market benefits, and network effects (Dyatlov, 2017a).

In the literature analysing network capital, there has long been an academic dispute as to whether network capital is capital. In particular, Robison et al. (2000) argued in their work that social capital has all "capital" qualities. Nevertheless, network capital differs from the other components of intellectual capital in that it is formed mainly in the interaction process between a company/individual and the unmanaged external environment (Kogteva et al., 2019). Network human capital can be defined as a set of capitalizable distributed network abilities, skills, and

competencies of managers, highly skilled workers, and the population at whole used for effective interaction via the Internet with network government structures (e-government structures), network business structures (e-business, innovative firms, offshore programming), network scientific and educational communities (network research groups, e-libraries, e-networks), network scientific and educational communities (network research groups, e-libraries, network universities), and social networks that are used to obtain various public goods, market benefits, and network effects (Dyatlov, 2017a, p. 72). New functions of intellectual network capital of specialists in the global digital economy are creativity, universality, polyfunctionality, network thinking and mobility, distance-network continuous education and self-education (Dyatlov, 2017b).

The digital economy, focusing on the new qualities of human capital listed above, *challenges* the existing education system in the training of highly qualified personnel. For example, in Russia, themes of higher education programs are formed and developed by the state on an instructional-administrative basis, often without considering the interests of production enterprises. As a result, it leads to a mismatch between the qualitative characteristics of the educational process and the professional competencies of employees required for the effective development of the enterprise (Shirinkina, 2018). However, business education must have guidelines for responding immediately to qualitative changes in industry demands. We need to understand what kind of society we are building and a person's place in it. So far, there is no answer to these questions. There is an idealized description of a digital society with its bright economic prospects, its need for highly skilled IT personnel, and the need to develop creative competencies in students. This attitude states that all people are potentially talented, gifted, and capable of creative intellectual activity. According to Leites (2008) and Semenov (2017), giftedness is always the result of a complex interaction of heredity (natural inclinations) and social environment, mediated by child activity (play, learning, work) and psychological mechanisms of personal self-development. Osipova (2019) emphasizes that giftedness is an unstable phenomenon and needs specific psychological and pedagogical support and assistance (depending on the individual characteristics of each child). The question arises: Does the human capital of the digital society include the part of the population that does not have innate intellectual abilities, or they have not been able to realize them? What role will they play, and how will they exist in this society? In these questions lie both the *challenge* of a digital society and the *risk* of dehumanizing society through smart education.

Discussion

Smart education is the answer to the massive digitalization of society under the pressure of Industry 4.0. Beginning innocently with the digitalization of education, where Internet technologies are used in the learning process, the transformation of the traditional system into smart education is moving to a new stage of

development, characterized by the interaction between man and machine. For the first phase, it was essential to have a purely technical saturation and provide educational institutions with computers, Internet access, and other supporting technological things. During this phase, which lasted until Covid 2019, the educational community created methodologies for using different devices, programs, and platforms. All these works were not systematic and were conducted either on the personal initiative of a teacher, as part of some educational institutions, or private initiatives on the part of the authorities.

However, in this chaos of growing practices, a picture of methodological shifts in the understanding of the smart education phenomenon is already emerging: the principle of nonlinear construction of educational programs, the characteristic of the student as a “network node”, the formation of a cloud of professions, a cloud of interests in the interdisciplinary space, etc.

All these qualitative changes were based on a network methodology, which relies on two fundamental tenets: the obligatory presence of social networks and the network schedule.

In 2019–2023, there have been many review articles in which the academic community has focused more on systematizing the experience of building a “smart education”. At the same time, an understanding of the new digital society, the role of human beings in it, and the possibilities and consequences of digitalization of education is emerging in scientific works. The concept of “Society 5.0” is being developed and has begun to be used to express the cooperation between society and technology. However, in this concept, scientists saw the danger to humanity in the contradictions between artificial intelligence and ethics. Saracel (2020) suggested the option of a “super-smart society” that reevaluates the relationship between humans and machines (p. 31). Salgues (2018) defined Society 5.0 as “the artificial intelligence society that strongly connects the physical and cyber spaces” (p. 1).

The ethical debate focuses on events involving scientific and biotechnological interference with human beings’ physical and cognitive structure. A new scientific trend, “transhumanism”, has emerged, arguing for the legitimacy and necessity of such intervention. Digitalization processes have had a serious impact on didactics. Among the descriptions of the negative impacts of digitalization on the classical didactic arsenal that we have indicated, positive expectations related explicitly to smart education are maturing. Walkington and Bernacki (2020) note the need for learning theories underlying the personalization of learning. In their opinion, even if these theories emerge, empirical support still needs to be improved. As a result of their study, the researchers offered several recommendations for improving research work in personalising learning. Arapova et al. (2022) offered a concept of an intelligent platform aimed at implementing an individual learning path according to the student’s basic level of knowledge and psychological type. Thanks to the opportunities provided by artificial intelligence, there is a chance to build a bridge between the processes of personalization of learning and individual approaches to developing the learner’s personality.

Conclusions

In our analysis of the emerging challenges and risks in the evolution of smart education, we assume that the development of smart technology is so rapid that society needs more time to grasp the possibilities. However, these technological possibilities are fascinating in their prospects. Smart education's challenges and risks are associated with the lack of clear guidelines, which are hard to build when you are amidst a significant change.

Nevertheless, identifying risk zones allows for activating scientific thought in search of either solutions to emerging problems or preventing their occurrence. The phenomenon of smart education is directly related to the digitalization processes implemented in the era of the fourth revolution. Each area of transformation of social and educational practices we have identified requires close attention from researchers from different academic disciplines. The nonlinear logic of large-scale changes requires a combined approach in the study of practices and the integration of scientific humanities and technological knowledge.

References

- Akhmadov, A., Mutsurova, Z., & Beterbieva, A. (2023). Innovative technologies in the educational process trends, prospects for development. *SHS Web of Conferences*, 172, 01013. <https://doi.org/10.1051/shsconf/202317201013>
- Alpaydm, Y., & Cihad, D. (2022). *Educational theory in the 21st century: Science, technology, society and education* (Maarif global education series). Palgrave Macmillan. <https://doi.org/10.1007/978-981-16-9640-4>
- Ananiadou, K., & Claro, M. (2009). *21st century skills and competencies for new millennium learners in OECD countries* (OECD Education Working Papers 41). OECD. <https://doi.org/10.1787/218525261154>
- Arapova, E. A., Kramarov, S. O., & Sakharova, L. V. (2022). Concept development of an intelligent platform aimed at implementing an individual learning path according to the Student's basic level of knowledge and psychological type. *Proceedings in Cybernetics*, 1(45), 6–15. <https://doi.org/10.34822/1999-7604-2022-1-6-15>
- Ardashkin, I. B., Borovinskaya, D. N., & Surovtsev, V. A. (2021). The epistemology of smart technologies: Is smart epistemology derived from smart education? *Education & Pedagogy Journal*, 1(1), 21–35. <https://doi.org/10.23951/2782-2575-2021-1-21-35>
- Avdeeva, I. L., Polyinin, A. V., & Golovina, T. A. (2019). Digitalization of industrial economic systems: Problems and consequences of modern technologies. *Izvestiya of Saratov University. New Episode. Series: Economy. Control. Right*, 19(3), 238–245. <https://doi.org/10.18500/1994-2540-2019-19-3-238-245>
- Barnes, J. A. (1954). Class and committees in Norwegian Paris Islands. *Human Relations*, 7, 43–44. <https://doi.org/10.1177/001872675400700102>
- Bayne, S. (2015). What is the matter with 'technology-enhanced learning'? *Learn Media Technol*, 40(1), 5–20. Retrieved September 18, 2023 from <https://www.learntechlib.org/p/153866/>
- Berman, N. D. (2017). To the question of digital literacy. Society of Russia: educational space, psychological structures and social. 8(6–2), 35–38. <https://doi.org/10.12731/2218-7405-2017-6-2-32-38>.
- Bernstein, B. (2003). *Class, codes and control*. Routledge.

- Bodrijar, Z. (1998). *Consumer society. His myths and structures*. SAGE Publications.
- Bosova, L. L., & Pavlov, D. I. (2019). Development of “new” literacy components when teaching informatics in primary school. *Science and School*, 3, 156–165. <http://nauka-i-shkola.ru/node/146>
- Bourdieu, P. (1986). The forms of capital. In J. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). Greenwood.
- Bresler, M. G. (2014). *Social networks and network communities of the information society: Monograph*. RIC BashGU.
- Burkhard, R. A. (2005). Knowledge visualization: The use of complementary visual representations for transfer knowledge. A model, a framework, and four new approaches. In S. Tergan & T. Keller (Eds.), *Knowledge and information visualization, searching for synergies*. Springer. <https://doi.org/10.3929/ETHZ-A-A-005004486/>
- Cambridge Dictionary. (2023). <https://dictionary.cambridge.org/dictionary/english/knowledge>. Available 9 Sept 2023.
- Castells, M. (2000). Materials for an exploratory theory of network society. *British Journal of Sociology*, 51(1), 5–24. <https://doi.org/10.1111/J.1468.2000.00005.X>
- Černý, M. (2020). University education and its pandemic response COVID-19. *E-Pedagogium*, 3, 32–45. <https://doi.org/10.5507/epd.2020.016>
- Cheok, M. L., Wong, S. L., Ayub, A. F. M., & Mahmud, R. (2020). ICT integration in Malaysian education scenario. In C. K. Looi, H. Zhang, Y. Gao, & L. Wu (Eds.), *ICT in education and implications for the belt and road initiative* (Lecture notes in educational technology). Springer. <https://doi.org/10.1007/978-981-15-6157-3>
- Comenius, J. A. (1967). *The great didactic*. Russell & Russell.
- Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., Magni, P., & Lam, S. (2020). COVID-19: 20 countries’ higher education intra-period digital pedagogy responses. *Journal of Applied Learning & Teaching*, 3, 1–20. <https://doi.org/10.37074/jalt.2020.3.1.7>
- Daniela, L. (2018). Smart pedagogy for technology enhanced learning. In L. Daniela (Ed.), *Didactics of smart pedagogy: Smart pedagogy for technology enhanced learning*. Springer. https://doi.org/10.1007/978-3-030-01551-0_1
- DiMaggio, P., & Hargittai, E. (2001). From the “digital divide” to “digital inequality”: Studying internet use as penetration increases (Working Paper, 47). Princeton University. https://culturalpolicy.princeton.edu/sites/culturalpolicy/files/wp15_dimaggio_hargittai.pdf
- DiMaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2004). *From unequal access to differentiated use: A literature review and agenda for research on digital inequality* (K. Neckerman, Ed.). Russel Sage Foundation. <https://doi.org/10.4324/9781003071709-13>.
- Dyatlov, S. A. (2017a). *Eniro-network hypercompetitive economy*. St. Petersburg State University of Economics.
- Dyatlov, S. A. (2017b). Network intellectual capital in the digital economy. In *Economic growth and legal policy priorities: Monograph* (pp. 17–23). Science and Education (IP Gulyaev G. Yu.).
- Giacosa, A. (2023). Comparing the experiences of university teachers and students in synchronous hybrid settings during and after the pandemic. *RiCOGNIZIONI. Rivista Di Lingue E Letterature Straniere E Culture Moderne*, 10(19). <https://doi.org/10.13135/2384-8987/7480>
- Hagemann, H. (2019). Economic opportunities for our grandchildren. *Questions of Economics*, 6, 60–69. <https://doi.org/10.4337/9781788118569.00035>
- Hargittai, E. (2002). Second-level digital divide: Differences in people’s online skills. *First Monday*, 7(4). <https://doi.org/10.5210/fm.v7i4.942>
- Hollands, R. G. (2008). Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City*, 12(3), 303–320. <https://doi.org/10.1080/13604810802479126>
- Illich, I. (1971). *Deschooling society*. Harper & Row.
- Jackson, N. C. (2019). Managing for competency with innovation change in higher education: Examining the pitfalls and pivots of digital transformation. *Business Horizons*, 62, 761–772. <https://doi.org/10.1016/j.bushor.2019.08.002>

- Jameson, J. (2019). Developing critical and theoretical approaches to educational technology research and practice. *British Journal of Educational Technology*, 50(3), 951–955. <https://doi.org/10.1111/bjet.12775>
- Järvelä, S., Gašević, D., Seppänen, T., Pechenizkiy, M., & Kirschner, P. A. (2020). Bridging learning sciences, machine learning and affective computing for understanding cognition and affect in collaborative learning. *British Journal of Educational Technology*, 51(6), 2391–2406. <https://doi.org/10.1111/bjet.12917>
- Job Creation and Local Economic Development. (2018). *Preparing for the future of work*. OECD. https://www.oecd-ilibrary.org/employment/jobcreation-and-local-economic-development-2018_9789264305342-en
- Job Creation and Local Economic Development. (2020). *Preparing for the future of work*. OECD. https://read.oecd-ilibrary.org/employment/job-creationand-local-economic-development-2020_b02b2f39-en#page62
- Kiel, L. D., & Elliott, E. W. (1996). *Chaos theory in social science, fundamentals and applications*. Elliott SEs University of Michigan.
- Klichowski, M., Bonanno, P., Jaskulska, S., Smaniotto Costa, C., de Lange, M., & Klauser, F. R. (2015). CyberParks as a new context for smart education: Theoretical background, assumptions, and pre-service teachers' rating. *American Journal of Educational Research*, 3(12A), 1–10. <https://doi.org/10.12691/education-3-12A-1>
- Kogteva, A. N., Gerasimova, N. A., Kulik, A. M., & Shevtsova, N. M. (2019). Network forms of human capital in conditions of digital transformation. *Bulletin of Voronezh State Agrarian University*, 4(63), 194–202. <https://doi.org/10.17238/issn2071-2243.2019.4.194>
- Koneva, A. V., & Lisenkova, A. A. (2019). Identity matrix in the digital age: Social challenges to overcome the anonymity. *Tomsk State University Journal of Cultural Studies and Art History*, 35, 14–27. <https://doi.org/10.17223/22220836/35/2>
- Krezhevskiykh, O. V. (2020). Nonlinear higher education: Methodology, regularities and possibility of implementation in practice. *Human Science: Humanities Studies*, 1(39), 48–56. <https://doi.org/10.17238/issn1998-5320.2020.39.48>
- Kurzweil, R. (2005). *The singularity is near: When humans transcend biology*. Viking Penguin.
- Leites, N. S. (2008). *Age giftedness and individual differences. Selected works*. Moscow Psychological and Social Institute, MODEK.
- Lektorskiy, V. A., Dubrovskiy, D. I., Ivanov, D. V., Katuninm, A. V., Mihajlov, I. F., Trufanova, E. O., Chertkova, E. L., Shhedrina, I. O., & Jakovleva, A. F. (2016). Human subjectivity in the light of modern challenges of cognitive science and information-cognitive technologies. Materials “round table”. *Philosophy Issues*, 10. http://vphil.ru/index.php?option=com_content&task=view&id=1500&Itemid=52
- Liu, H., Yue, L., & Wang, Q. S. (2022, April 5–9 2021). *Localization of global education and its leadership practices: A case of China*. [Section global issues conference proceedings] The 6th global issues conference. Worldwide online. 10(1). <http://gpejournal.org/index.php/GPEJ/issue/view/12>
- Lobanov, O. S., Ostroumov, A. A., & Melnikova, E. F. (2014). Cloud information space as a stage of systematic development of information society. *International Research Journal*, 11-3(30), 50–51. <http://research-journal.org/archive/11-30-2014-november/oblachnoe-informacionnoe-prostranstvo-kak-etap-sistemnogo-razvitiya-informacionnogo-obshhestva>
- Longworth, N. (2003). *Lifelong learning in action: Transforming education for the 21st century*. Kogan Page.
- Middleton, A. (2015). *Smart learning: Teaching and learning with smartphones and tablets in post-compulsory education*. Sheffield Hallam University.
- Mitri, S., Floreano, D., & Keller, L. (2009). The evolution of information suppression in communicating robots with conflicting interests. *PNAS*, 106(37), 15786–15790. <https://doi.org/10.1073/pnas.0903152106>
- Mohajezad, H., & Schrader, J. (2022). Transfer from research to practice – A scoping review about transfer strategies in the field of research on digital media. *Computers and Education Open*, 3. <https://doi.org/10.1016/j.caeo.2022.100111>

- Novikov, A. M., & Novikov, D. A. (2013). *Methodology: Dictionary of the system of basic concepts*. Librokom.
- Odegov, Y. G., & Pavlova, V. V. (2018). New technologies and their impact on the labour market. *Living Standards of the Population of Russian Regions*, 2, 60–70. <https://doi.org/10.24411/1999-9836-2018-10015>
- Osipova, M. B. (2019). *Gifted children: Problems of identification, development and psychological and pedagogical support in the system of general education*. NTF GAOU DPO SO “IRO”.
- Plaksin, M. A. (2017). Propaedeutics of parallel computing in school informatics. Network Schedule. *Informatics at School*, 3(126), 29–35. <https://doi.org/10.25559/SITITO.14.201804.1000-1011>
- Pozdeeva, S. I. (2016). On the problem of formation of younger schoolchildren’s abilities to work with informational text. *Tomsk State Pedagogical University Bulletin*, 5(170), 28–31. https://vestnik.tspu.edu.ru/en/archive.html?year=2016&issue=5&article_id=5818/
- Redecker, C. (2017). European framework for the digital competence of educators: DigCompEdu. In Y. Punie (Ed.), *EUR 28775 EN*. Publications Office of the European Union.
- Robinson, L., Cotton, S. R., Ono, H., Quan-Haase, A., Mesch, G., Chen, W., Schulz, J., Hale, T. M., & Stern, M. J. (2015). Digital inequalities and why they matter. *Information Communication & Society*, 18(5), 569–582. <https://doi.org/10.1080/1369118X.2015.1012532>
- Rogers, C. (1951). *Client-centered therapy: Its current practice, implications, and theory*. Houghton Mifflin.
- Salgues, B. (2018). *Society 5.0: Industry of the future, technologies, methods and tools*. Wiley.
- Saracel, N. (2020). Society 5.0: Super smart society. *Social Sciences Research Journal (SSRJ)*, 9(2), 26–34. <https://dergipark.org.tr/tr/download/article-file/1111569>
- Schultz, T. (1968). *Human capital in the international encyclopedia of the social sciences* (Vol. 6). The Macmillan Publishers.
- Schwab, K. (2016). *The fourth industrial revolution*. Eksmo.
- Selwyn, N. (2021). The human labour of school data: Exploring the production of digital data in schools. *Oxford Review of Education*, 47(3), 353–368. <https://doi.org/10.1080/03054985.2020.1835628>
- Semenov, I. N. (2017). Overview of the directions of the Russian psychology of creativity and giftedness. *Psychology. Historical and Critical Reviews and Modern Research*, 6(6A), 3–22. <http://www.publishing-vak.ru/archive-2017/psychology-6.htm>
- Semenovskikh, T. V. (2014). The phenomenon of “clip thinking” in the educational environment of universities. *Naukovedenie*, 5(24) <http://naukovedenie.ru/PDF/105PVN514.pdf>
- Sharonova, S., Avdeeva, E. (2019, July 6–9). Transformation of educational landscape in the era of smart society. *Proceedings of the 13th international multi-conference on society, cybernetics and informatics*. International Institute of Informatics and Systemics, Orlando, Florida, USA.
- Shirinkina, E. V. (2018). Efficiency management of intellectual labor workers in higher educational institutions. *Human Resources and Intellectual Resources Management in Russia*, 1, 12–16. https://doi.org/10.12737/article_5a9ce8a0e6f7e4.54032761
- Siddiqui, A. W., Raza, S. A., & Tariq, Z. M. (2018). A web-based group decision support system for academic term preparation. *Decision Support Systems*, 114, 1–17. <https://doi.org/10.1016/j.dss.2018.08.005>
- Tergan, S.-O., & Keller, T. (2005). *Knowledge and information visualization* (LNCS 3426). Springer.
- Terry, K. P. (2016). Review of integrating technology and pedagogy: Improving teaching and learning in higher education by James A. Bernauer and Lawrence A. Tomei. *TechTrends*, 60(4), 402–403. <https://doi.org/10.1007/s11528-016-0065-0>
- The Ministry of Education of the Russian Federation. (2022). *National Project Education 2019–2022*. <https://edu.gov.ru/national-project/>
- Tikhomirov, V. P. (2011). The world on the way of smart education. New opportunities for development. *Open Education*, 3, 22–28. https://www.kstu.kz/wp-content/uploads/docs/innovations/otkrytoe_obrazovanie/otkrytoe_obrazovanie_%E2%84%963_2011/%E2%84%963_2011_22.pdf

- Unt, I. (1990). *Individualization and differentiation of training*. Pedagogy.
- Van Dijk, J. (2020). *The digital divide*. Polity Press.
- Walkington, C., & Bernacki, M. L. (2020). Appraising research on personalized learning: Definitions, theoretical alignment, advancements, and future directions. *Journal of Research on Technology in Education*, 52(3), 235–252. <https://doi.org/10.1080/15391523.2020.1747757>
- Woodcock, J. (2018). Digital labour in the university: understanding the transformations of academic work in the UK. TripleC: communication, Capitalism & Critique. *Open Access Journal for a Global Sustainable Information Society*, 16(1), 129–142. <https://doi.org/10.31269/triplec.v16i1.880>
- Yadov, V. A. (2000). Social and socio-psychological mechanisms of personality identity formation. In *Psychology of self-consciousness* (pp. 589–601). Samara.
- Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments*, 3(1). <https://doi.org/10.1186/s40561-0160026-2>

Chapter 6

The Role of Computers in Education in the Era of the Fourth Industrial Revolution



Michael Gr. Voskoglou 

Introduction

Computers have become a valuable tool for all steps of education, providing through the web a wealth of information for learners and instructors (Voskoglou & Buckley, 2012). The use of the proper software and the “clever” methods of *artificial intelligence (AI)* (Kasstranis, 2019; Mitchell, 2019) applied with the help of computers enhance the students’ critical thinking and imagination and their problem-solving skills. Several didactic methods and learning theories have been developed during the last 30–40 years, based on the use of computers to increase the student interest in the learning objects, improve the quality of teaching (Arnon et al., 2014; Bergman & Sams, 2012; Voskoglou, 2008; Siemens, 2005), etc. There also exist reports, however, against the use of computers and other digital devices in classrooms, arguing that the student’s attention is distracted by their presence (Payne Carter et al., 2016).

A considerable number of computer specialists and other scientists of related disciplines have already claimed that, shortly, computers and other smart devices of AI will replace teachers the same way as cars replaced horses some decades ago! Although this claim sounds rather like an exaggeration, it is more than certain that the role of the teacher in the classroom will change dramatically in future, providing a form of guidance to students, permitting them to explore on their own rather than performing traditional lectures.

The forthcoming era of the *Fourth Industrial Revolution (4IR)* is characterized by the advanced *Internet of Things (IoT)* providing energy, goods, and services at the right time and any place and by the extensive use of *cyber-physical systems* (e.g. robots, autonomous vehicles and control systems, distance medicine, etc.), which

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will make our lives easier (Schwab, 2016). The present chapter discusses the role of computers in education in the era of the 4IR.

The rest of the chapter is organized as follows: The second section studies *connectivism*, a new learning theory in the digital age, concerning the traditional learning theories of the twentieth century. Emphasis is also given to *computational thinking (CT)* (Wing, 2006), a new mode of thinking that, combined with critical thinking, has become necessary for solving complex problems nowadays. The third section reviews the computer-aided teaching methods developed during the last decades and examines the new role of the teacher in the classroom in the digital era. The fourth section discusses the advantages and limitations of *e-learning* (Goyal, 2012) concerning traditional classroom learning. Section “[Applications of artificial intelligence to education](#)” is devoted to studying the most critical applications of AI to education, especially those related to the use of computers, like *smart learning systems (SLSs)* (Salem & Parusheva, 2018). The chapter closes with a general discussion about the 4IR presented in the sixth section and the conclusions in the seventh section.

The topics that will be covered in this chapter include:

- Connectivism and computational thinking.
- Computer-aided teaching methods.
- The new role of the teacher in the classroom.
- Advantages and disadvantages of e-learning.
- Applications of AI to education and ethical rules for their use.
- Influences of the 4IR on society and education.
- General conclusions.

Connectivism Vs Traditional Learning Theories

Roughly speaking, *learning*, the most fundamental component of human cognition, is the acquisition or enhancement of one’s knowledge and skills. The nature of learning was among the primary human spiritual investigations from the very beginning of human civilization. The question of whether knowledge comes from intellectual reasoning (*rationalism*) or through external observation (*empiricism*), raised by the ancient Greek philosophers Socrates, Plato, and Aristotle some hundred years BC, became during the seventeenth and eighteenth centuries AC the reason for an intense dispute between the rationalist (Descartes, Spinoza, Leibniz, etc.) and the empiricist philosophers (Hume, Bacon, Locke, etc.) of that time.

During the twentieth century, essentially the same question was expressed: whether people learn by changing their behaviour due to environmental influences (*behaviourism*) (Cherry, 2019) or by using their brains to construct or expand their knowledge based on new data (*cognitivism*) (Wallace et al., 2007). Von Clasersfeld, based on Piaget’s ideas about learning (Miller, 2011), introduced the theory of *constructivism* formally in the 1970s, according to which knowledge is not passively

acquired from the environment. However, it is actively constructed by the cognitive mechanisms of the learner (Taber, 2011). Combining the principles of constructivism with Vygotsky's views of social development (Crawford, 1996) created the framework of *social constructivism* (McKinley, 2015), which is currently the most popular among traditional learning theories. Social constructivism argues that learning occurs within a sociocultural setting, where shared meanings are formed through negotiation, leading to common knowledge. This happens, for example, with the *communities of practice*, i.e. groups of specialists or practitioners on the same or similar subjects regularly discussing their shared interests (Wenger, 1998; Voskoglou, 2019a).

The traditional learning theories were developed before the appearance of digital technologies. Therefore, a common principle of these theories was that learning occurs inside the individual. However, this only holds sometimes since people frequently obtain information stored in digital databases called *actionable knowledge*. Consequently, a new learning theory that was introduced by Siemens (2005) and Dowens (2005) and termed *connectivism* appeared in our digital era. The main idea of connectivism is that learning what we need by plugging into sources (connections) is more important than what we already know. In other words, connectivism sees knowledge as a network and learning as creating new connections between nodes for expanding the network.

Connectivism is an amalgamation of principles referred to as *artificial neural networks (ANNs)*, to *self-organization* theory and the theory of *chaos*. ANNs are groups of artificial neurons or nodes connected and mimicking the operation of biological networks. Each artificial neuron performs a particular minor operation, and the overall ANN's operation is the weighted sum of all these operations (Papilinski, 2005; Ibrahim, 2016). An ANN must be fed with teaching patterns to be able to change, according to some already imposed learning rules, its weighting function concerning the received at each time input. Suitable computer programs are used for handling the large number of necessary calculations in ANNs during the learning process (*neural computing*) (Buckley & Hayashi, 1994). ANNs are highly efficient for solving problems in which there are no specific rules for their solution.

On the other hand, self-organization is the formation of well-organized structures or behaviours under random conditions (Rocha, 1998). In this process, a learning system can change its structure to classify its interaction with the environment. Finally, the chaos theory, which generally recognizes the connection of everything to everything, states that in a learning process, the meaning already exists, and the learners' challenge is to recognize its hidden patterns. This contradicts the constructivist view that learners attempt to obtain understanding by meaning-making tasks.

Siemens (2008) answered five questions for distinguishing the learning theories for behaviourism, cognitivism, constructivism, and connectivism, raised by Ertmer and Newby (Mergel, 1998). In this way, he created a framework for organizing and comparing the previous theories concerning how learning occurs, what factors influence it, what is the role of memory, how transfer occurs, and what types of learning are best explained by each. He concluded that behaviourism is more

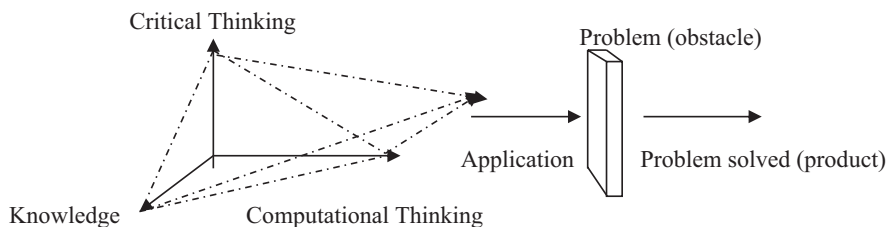


Fig. 6.1 The problem-solving model of Voskoglou and Buckley

suitable for task-based learning, cognitivism for reasoning, clear objectives and problem-solving, constructivism for social and vague (ill-defined) learning, connectivism for complex learning, and rapidly changing core and diverse knowledge sources.

Connectivism received various criticisms, considering it an ineffective alone learning theory, because it misses crucial concepts like reflection, learning from failures, error detection/correction, and inquiry (e.g. Verhagen, 2010; Chati, 2010), etc., or arguing that what is needed in our digital era is not a new theory for learning but a framework integrating the existing theories to guide the design of online learning materials (Ally, 2008). An Al Dahdouh's (2017) study revealed surprisingly that instructors usually apply constructivism principles to teach ANNs, whereas connectivism principles are used only when the knowledge is unknown.

The use of new technologies in the digital age resulted in several new composite and complex problems, the solution of which, apart from *critical thinking*, also needs another mode of thinking, termed *computational thinking (CT)* (Wing, 2006). CT is defined as a person's ability to solve problems like computers. CT synthesizes other modes of thinking, including abstract, logical, constructive, algorithmic, and modelling thinking (Liu & Wang, 2010).

Voskoglou and Buckley (2012) presented a model illustrating how CT combines critical thinking and existing knowledge to solve complex problems. In this 3D model (Fig. 6.1), the problem is considered an obstacle, and the resultant of knowledge, critical thinking, and CT is applied to pass through this obstacle. Studies reported in the literature suggest starting training students in CT as early as possible and, in any case, before they start learning programming (Kazimoglu et al., 2011).

Computer-Aided Teaching Methods and the New Role of the Teacher in the Classroom

The target of teaching is to promote the learning process. Some decades ago, the prevalent teaching method was *explicit instruction*, based on cognitivism and centred on the instructor's effort to transfer the new knowledge to students with clear statements and explanations and supported practice (Doabler & Fien, 2013).

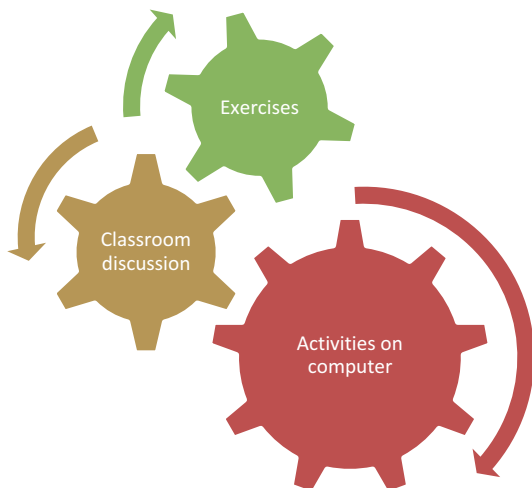
The sociocultural theories for learning have recently become very popular, especially for school education. As a result, new teaching approaches have been introduced, like *problem-based learning* (Voskoglou, 2010), *application-oriented teaching* (Voskoglou, 2005), *inquiry-based learning* through creative exploration (Jaworski, 2006), etc. A synthesis of the previous approaches resulted in the *5E's instructional treatment*, which is based on the principles of social constructivism. The term “5E's” is due to the initial letters of the five steps of the method, including engagement, exploration, explanation, elaboration, and evaluation. The 5E's instruction focuses on the interaction between teacher and students, connecting the already existing knowledge to the new knowledge with the help of the new student experiences. More details about the “5E's” instructional treatment and examples of its application to teaching can be found in Hee et al. (2013), Voskoglou (2019b), etc.

Several computer-aided didactic methods have been proposed in the last few decades for improving the quality of learning. Ed Dubinsky and his collaborators designed during the 1990s the *APOS/ACE* instructional treatment for teaching mathematics (Arnon et al., 2014). The central idea of the APOS, the theoretical part of Dubinsky's framework, is that teaching mathematics can be focused on using computers to help students build solid mental structures for tackling more advanced mathematical topics. This idea is highly based on Piaget's learning theory and the principles of social constructivism.

The acronym APOS is due to the initial letters of the successive mental states of this approach, which are **actions**, **processes**, **objects**, and **schemas**. The mental activities involved in the APOS theory are the *interiorization* of an action to a process and the *encapsulation* of a process to an object. Concerning the decimal representation of the real numbers, for example, the concept of an actual number in the action level is understood through its finite decimal approximations. The interiorization of this action to a process involves the understanding and the symbolic representation of the infinite decimal numbers and their distinction between periodical and non-periodical numbers. Further, encapsulating this process to an object involves the recognition of the equivalence between periodical numbers and fractions and of the transcendental numbers as a particular class of irrational numbers, as well as the representation of the real numbers in the form of Dedekind cuts. Finally, the conceptualization of the real numbers to a cognitive schema involves consolidating the fact that they have the algebraic structure of a field. Implementing the APOS for teaching a mathematical topic presumes a theoretical analysis of the concepts to be studied, called *genetic decomposition*.

The ACE cycle, including activities on **the computer**, **classroom discussion**, and **exercises**, is the practical part of Dubinsky's model, which is usually repeated several times (Fig. 6.2). According to the ACE approach, students are expected to transfer from a mental state (e.g. action) to the next and more advanced one (e.g. process) by participating in proper computer activities, designed by the instructor or by other experts. The same activities, but without using the computer, are repeated and discussed in the classroom. In the last step, exercises are given to students as homework for embedding the new knowledge.

Fig. 6.2 The ACE cycle



Applications of the APOS/ACE method to teaching, especially for the tertiary level, can be found in Arnon et al. (2014) and many other works of Dubinsky's research team and other authors. Applications to the teaching of irrational numbers and polar coordinates can also be found in earlier works of the present author (Voskoglou, 2013; Borji & Voskoglou, 2016, etc.).

Another computer-aided teaching method developed in the last two decades is *flipped learning* (Bergman & Sams, 2012; Lage et al., 2000; Lee et al., 2017). Following this approach, the new knowledge is obtained outside the classroom using suitably selected software, video presentations, or other digital means. On the contrary, the traditional homework is done in the classroom, directed and supervised by the teacher. In other words, the traditional teaching procedure is inverted to achieve better learning results. Examples of flipped learning applications to teaching can be found in Bergman and Sams (2012), Lee et al. (2017) and several other sources.

A traditional strategy for solving a given problem is to exploit and adequately modify the solution of a similar problem solved in the past, termed an analogous problem. Using computers enabled the creation and easy maintenance of large digital "libraries" of analogous problems, referred to as past cases, and the retrieval of the most suitable ones to solve a given problem. This process, called *case-based reasoning (CBR)*, is widely used today not only in diagnostic, commercial, industrial, and many other applications but also for educational purposes (Voskoglou, 2008; Voskoglou & Salem, 2014). A vehicle engineer, for example, who fixes a car based on the repair procedure of a previous car presenting similar problems, or a doctor, who treats a patient guided by the successful treatment given to a previous patient with the same symptoms, uses the CBR methodology.

CBR has been formalized as a four-step process including *retrieval* (R_1) of the suitable past case from the corresponding digital library, *reuse* (R_2) of the information in that case for obtaining a candidate solution of the given problem, *revision* (R_3) of the obtained solution, and *retaining* (R_4) the new case in the library, likely

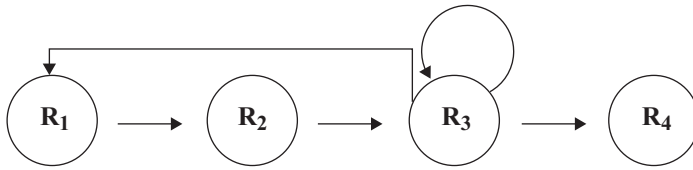


Fig. 6.3 Flow diagram of the CBR process

to be useful for future problem-solving. A simplified flow diagram of this process is sketched in Fig. 6.3.

The suitability of the candidate solution of the given problem, obtained at step R_2 , is checked for success at the next step, R_3 . In case of failure, the solution is corrected. If a correction is impossible, the process must return to R_1 to retrieve a more suitable past case from the library. A more detailed flow chart of the CBR process can be found in (Kolodner, 1991).

As digital means in education grows, learners' autonomy in obtaining information continuously increases. As a result, new models have been developed for the teacher's role and interaction with students in the classroom (Siemens, 2008; Seely Brown, 2006; Fisher, 2007). In these models, the teacher is compared with an administrator, who observes and guides the student's activities and assists them in creating learning networks. Attention is also given in these models to the critical role of the instructional designers in directing teachers to the use of the proper digital tools and open education resources.

Computers, however, must only be considered tools supporting teaching and learning rather than devices that can do everything. This is successfully illustrated by the well-known, from the appearance of computers, credo "rubbish in, rubbish out", characterizing their function. The student's practice with arithmetic and algebraic calculations and with the rediscovery of the proofs must be continued forever. Otherwise, humans will eventually lose the ability to deal with numbers and symbols and to think critically (Voskoglou & Buckley, 2012).

Ethical or social concerns also arise with the increased integration of technology in classrooms. This includes issues related to privacy, access to technology, and the potential impact on interpersonal interactions. Computer specialists and educators must study all these seriously, and the proper solutions to the corresponding problems must be found and widely communicated to the users.

Advantages and Limitations of the Distance Concerning Classroom Learning

Thanks to technological progress, the human-to-human contact that was necessary some decades ago for teaching and learning can be partially replaced by virtual teaching using computers, videos, etc. However, many studies in various countries,

especially in the post-COVID era, show that human contact cannot be replaced entirely; it is necessary for socialization, the formation of sociocultural skills, values, and a person's psychological development.

The effort to introduce distance learning, usually referred to as *e-learning*, with the help of computers started during the 1980s, when educational research in the USA revealed that students receiving individual tutoring performed better than those who did not (Bloom, 1984). Two big companies in China led this effort: Squirrel, which drives forward AI tutors to replace teachers, and Alo7, which provides a learning platform supplementary to the traditional classroom (Yang, 2019). The engineers of Squirrel collaborate with specialists and educators to divide a topic into the minor possible conceptual sections to determine and treat the student's difficulties in the best possible way. In general, implementing AI methods for teaching and learning is at a pretty advanced level in China, especially for higher education. The recent COVID-19 pandemic also firmly pushed for further development of e-learning techniques worldwide.

E-learning provides access to the learning material at any time and place, in contrast to traditional learning, which requires the physical presence of the learner in the classroom. The e-learning material could be easily modified for similar uses in future. It can be used simultaneously by a large population spread worldwide because it can be sent electronically to remote learners with the help of a computer network. This is particularly useful for the people of the developing countries, who, due to budgetary constraints, it is usually challenging to travel abroad to participate in scientific, educational and vocational events. Through e-learning, students can quickly learn what they need by skipping unnecessary information. However, the student must have specific knowledge to understand what information is unnecessary.

Note that shortly, many jobs are expected to be lost because computers, robots, and other "clever" machines of AI will replace humans. At the same time, however, new jobs will be created concerning these machines' production, maintenance, control, etc. This means many people will face the challenge of changing jobs, which usually requires extra training. Such training is now available in their free time through e-learning at a much lower cost than traditional learning, which includes fees, books and probably travel, boarding, accommodation, etc. (Goyal, 2012). In conclusion, e-learning appears in the era of 4IR as a potential alternative to traditional learning, especially in remote lifelong learning and training cases. It can also be used as a complement to the classroom instruction.

Certain limitations, however, exist with e-learning. The physical presence of the learners in the classroom, for example, facilitates the instant solution of all their inquiries with the help of the teacher. Relative research has shown that digital devices, which are usually necessary for the e-learning process, distract the learners' attention, especially the young ones (Payne Carter et al., 2016). The acquisition of new information is significant, but more important for the learners is to develop their *critical* and *creative thinking* skills, which will enable them to question, analyse, interpret, evaluate, **and** make judgements about what they read, hear, say, or write and generally to think in a manner that solves problems. It is questionable, however, if this can be achieved only with the help of suitably designed software

and the other “clever” methods of AI without the teacher’s guidance. Since all these “clever” methods have been designed and implemented by humans, it is difficult to imagine that they could reach, or even exceed, the quality of the human brain and sense. It should be noted, however, that in the conditions of learning the algorithm, students develop *sequential thinking*, i.e. the ability to process information in an orderly prescribed manner involving a step-by-step progression, where a response to a step must be obtained before another step is taken.

Applications of Artificial Intelligence to Education

AI is the branch of computer science, which studies the theory and practice of creating “smart” devices mimicking human reasoning and behaviour. Among others, AI aims at making computers able to perform autonomous improvements without needing the commands of humans. AI synthesizes techniques and methods from various other disciplines, including mathematics, engineering, biology, linguistics, philosophy, psychology, etc. (Kastranis, 2019; Mitchell, 2019).

The use of computers in education is combined with techniques and methods of AI that have brought significant benefits to the teaching and learning processes, student assessment, teachers’ pre-service and in-service training, and several other educational activities (Voskoglou & Salem, 2020). In this section, we briefly present some of the most critical applications of AI to education, especially those connected with the use of computers.

Machine learning (ML) is the branch of AI that designs and implements computer programs that learn by themselves from training data sets (Das et al., 2015). In the supervised ML, both the input and output data are known, as it happens, for example, with the positive integers (input) and the sequence of their squares 1, 4, 9, 16, 25,...(output). In unsupervised ML, on the contrary, only the input data are known, and the algorithms used learn more about the output data.

In the last decades, ML methods have been used to develop *smart learning systems (SLSs)* web-based software acting as a tutor (Salem & Parusheva, 2018). The design of an SLS involves the construction of its knowledge base, the choice of suitable reasoning and inference methodologies, and the selection of suitable authoring shells. The shells enable the teacher to access the SLS knowledge base without any programming skills and facilitate entry into the base of examples and applications. *Ontologies* are used in an SLS to help search learning and pedagogical sources on the web. The ontologies also work as translators in chains of heterogeneous educational systems. It is recalled that the ontologies used in computer science are knowledge-based systems designed to share knowledge among computers or computers and people (Tankelevcienca & Damasevicius, 2009).

Deep learning (DL) (Arnold et al., 2011) is a unique form of ML, its models being ANNs with many layers. The DL models are suitable for solving complex problems, like natural language processing, computer vision, motion of self-driving vehicles, etc. In 2017, a team at Google Brain introduced the *transformers*, a type of

DL model that adopts a self-attention mechanism, weighing the significance of each input part (Vaswani et al., 2017). The transformers wildly succeeded in tasks like machine translation and time series prediction. Many models of transformers have been designed, like GPT-2, GPT-3, GPT-4, LaMDA, BERT, XLNet, etc., to converse with humans in natural language, providing accurate answers to a great variety of questions. A *generative AI (GenAI)* model is an AI system capable of generating text, codes for creating new computer programs, visual images, and music “by identifying patterns in large quantities of training data, and then creating original material that has similar characteristics” (Pasick, 2023). Notable GenAI models are the ChatGPT built by OpenAI using GPT-3 and GPT-4 and Bard built by Google using LaMDA. *Social robots*, designed to interact with humans and other robots, are going to play a significant role in future education, too, like Tico, a robot that enhances children’s motivation in the classroom, and Bandit, designed for teaching social behaviour in autistic children (Breazeal, 2002; Taipale et al., 2015).

Soft computing (SC), a term introduced by Zadeh (1994), is the branch of AI mimicking how humans think, decide, and learn under conditions of uncertainty and imprecision. SC includes the topics of *fuzzy logic (FL)*, *probabilistic* and, in particular, *Bayesian reasoning (BR)*, the already mentioned *AANs* and *genetic algorithms (GAs)*. These topics are complementary and can be used simultaneously for solving difficult everyday life and science problems, which cannot or need to be more complex to be modelled mathematically. As the use of computers increases and their cost is reduced, SC has become crucial as a significant research object in automatic control engineering.

The infinite-valued in the unit interval $[0, 1]$ FL completes and extends Aristotle’s traditional *bivalent logic (BL)*. FL was introduced by Zadeh (1973) with the help of the notion of *the fuzzy set (FS)* (Zadeh, 1965) for tackling mathematically the existing in everyday life partial truths, as well as the definitions with no clear boundaries (e.g. high mountains, good players, etc.). Later, however, when the *membership functions* were interpreted as *possibility distributions* (Dubois & Prade, 2001), FL was also used for tackling the existing in everyday life and science *uncertainty*.

It is recalled that an FS A in the universal set U of the discourse is defined with the help of its membership function $m: U \rightarrow [0, 1]$. The closer $m(x)$ to 1, the better x satisfies the characteristic property of A for each x in U . The membership function is a generalization of the characteristic function of crisp sets. We refer to facts on FSs and their connection to their uncertainty (Klir & Folger, 1988). FSs have already found many vital applications in almost all sectors of human activity, the most characteristic being *fuzzy control* (Mamdani & Assilian, 1975; Sugeno, 1985; Voskoglou, 2020b). FSs and FL have been introduced recently in the syllabuses of several university departments, especially in postgraduate programs (Voskoglou, 2019c), and have also been used for student and teacher assessment (Voskoglou, 2019d).

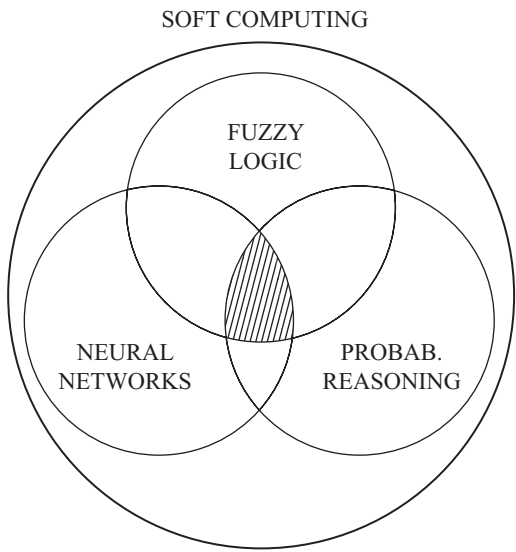
Zadeh (1978) clarified the relationship between possibility and probability by stating that whatever is probable must be primarily possible. Probability theory and related *statistics* have gained a primary position among the subjects taught even in school education. Probability, however, studies the evolution of future events, whereas statistics obtains conclusions about past events.

Based on the principles of BL, probability has been proven sufficient to tackle only the cases of uncertainty due to *randomness* (Kosko, 1990), e.g. games of chance. On the other hand, FL tackles other forms of uncertainty, including *vagueness* (e.g. the difficulty distinguishing between a good and a mediocre student). As a result, the proposed probabilistic logic proposed by Jaynes (2011) *probabilistic logic* is subordinate to FL. It is worth noting, however, that probabilities and the membership degrees of FSs, although they act on the same interval [0, 1], differ. For example, the expression “The probability that Peter is a good player is 0.8” means that Peter, who, according to Aristotle’s principle of the *excluded middle*, is either a good player or not and has, according to his past performance, an 80% probability of being a good player. On the contrary, the expression “The membership degree of Peter in the FS of good players is 0.8”, according to Lukasiewicz’s principle of *valence* holding in the multiple-valued logic, means that Peter is instead a good player.

The well-known for calculating the conditional probabilities *Bayes’ rule* is traced in many everyday life and science situations (Lejewski, 1967). Today, BR links BL and FL (Athanasopoulos & Voskoglou, 2020, Section 5). Surprisingly, BR has recently been proven to be involved in most of the mechanisms of the human brain’s function (Bertseh McGrayne, 2012), making it an essential tool for AI. Brockman (2015) has already expressed fears that the Bayesian machines of AI could become too smart in future, leaving humans a second role only! All these justify Sir Jeffrey’s characterization of BR as the “Pythagorean theorem of probability theory” (Jeffreys, 1973).

The relationships among ANNs, FL, and probabilistic reasoning within the broader class of SC are represented graphically in Fig. 6.4, where the intersections represent probabilistic approaches to ANNs and FL systems, Bayesian Reasoning and *neuro-fuzzy systems*, which are hybrid systems using a learning algorithm from

Fig. 6.4 FL, ANNs, and probabilistic reasoning within the broader class of SC



an ANN to determine their fuzzy parameters, e.g. the *adaptive neuro-fuzzy inference systems (ANFIS)* (Jang, 1997).

Following the introduction of FSs, a series of generalizations and alternative theories have been developed during the last decades for managing better the existing real-world uncertainty, including *interval-valued FSs*, *type - n FSs* ($n \geq 2$), *intuitionistic FSs*, *neutrosophic sets*, *soft sets*, *rough sets*, and *grey systems* (Voskoglou, 2019d). None of these theories alone can effectively tackle all the forms of uncertainty, but their combination forms an adequate framework for this purpose.

GAs emulate the natural evolution for finding the best solution to real-life optimization problems. For this, they create successive “generations” of possible solutions, evaluated by a suitably chosen *fitness function* (Ibrahim, 2016; Banztaf et al., 1998). For example, a GA can search several alternatives for the best solution for constructing a complex device. GAs have found successful applications in many sectors, such as biomedical and control engineering, code-breaking, automated manufacturing and design, etc.

Despite the practical usefulness and importance of the techniques of SC, however, their application has some limitations. For example, the definition of the membership function of an FS is not unique, depending upon the “signals” each observer receives from the environment. As we already have seen, probability is suitable only for tackling the uncertainty due to randomness. The ANNs cannot be used as universal tools for solving related problems, because no general methodology exists for training and verifying them. Excessive training may also be required in complex cases. The application of GAs, which are usually designed for special applications only, also has several difficulties, such as the frequently needed expensive evaluation of their fitness function; the existing, in some instances, vagueness about their termination process; their tendency to converge to local optima rather than to the global one; etc.

Discussion

The first two industrial revolutions, which took place from the end of the eighteenth century until the middle of the twentieth century, were characterized by replacing human hands and the power of animals with machines as a means of production. The parallel development of transportation led to the establishing big industries and companies internationally, facilitating the mass production of goods and improving social services. The third industrial revolution, otherwise known as the *era of automation*, which took place from the middle of the twentieth century until recently, was characterized by the gradual replacement of humans with computers as means of control and led humanity to its present digital age (Voskoglou, 2020b).

Currently, we are at the beginning of the 4IR, where AI, advanced Internet technology, renewable energy, the 3D printing, and the development of cyber-physical systems will merge to lead humanity to a new era of progress and well-being, provided, of course, that no mistakes and wrong behaviours by humans will interfere.

The new technologies will enable the distribution of electrical energy worldwide. They will allow smart home and household devices to communicate via the advanced IoT, providing goods and services at the right time and place (Schwab, 2016; Rifkin, 2014). However, all these will substantially change our lives, habits and behaviours. As we have already mentioned, for example, computers, robots, and other “clever” devices of AI are expected to replace humans in various routine jobs. However, simultaneously, they will create new jobs related to the previous devices’ production, maintenance, and control. Consequently, many people will face the challenge of changing their jobs.

Another serious matter is the introduction of *ethical rules* for the safe, transparent, and legal use of AI facilities through the web (AI Ethics Framework, 2020). Serious efforts have been already started in the USA, in the European Union and in other developed countries for “building up” a strict legislative framework about this, which, together with the continuously advancing security measures applied, will protect the users, the companies, and the public organizations from the hackers and the other dangerous “pirates” of the web.

Spectacular changes are expected to happen in education, too, where AI’s “smart” methods, with the help of computers and the advanced IoT, will play a dominant role. Therefore, there is an urgent need for specialists in the field to propose suitable practices and methods for students and teachers to absorb smoothly the forthcoming changes.

Conclusions

The present work investigated the role computers will play in education in the just-beginning era of 4IR. The changes that already took place or are expected to happen for teaching and learning were discussed, as well as the advantages and limitations of e-learning concerning traditional learning in the classroom. The current and future applications of AI to education, with the help of computers and the advanced IoT, the future role of the teacher in the classroom, as well as the necessary measures and ethical rules for the security of the web, were also examined. It was emphasized, however, that computers must not be considered as being able to do everything in the area of education (and not only) but simply as devices that, apart from providing a wealth of information to teachers and learners, can support and facilitate in a great deal the teaching and learning processes.

References

- Al Dahdouh, A. (2017). Does artificial neural network support connectivism’s assumptions? *International Journal of Instructional Technology and Distance Learning*, 14(3), 3–26.
- Ally, M. (2008). Foundations of educational theory in online learning. In Anderson, T. (Ed.), *The theory and practice of online learning*. http://www.aupress.ca/index.php/book_s/120146

- Arnold, L., Rebecchi, S., Chevallier, S., & Paugam-Moisy, H. (2011). *An introduction to deep learning*. In Proceedings of the European symposium on artificial neural networks, Bruges, pp. 477–488.
- Arnon, I., Cottrill, J., Dubinsky, E., Oktac, A., Roa, S., Trigueros, M., & Weller, K. (2014). *APOS theory: A framework for research and curriculum development in mathematics education*. Springer.
- Artificial Intelligence Ethics Framework for the Intelligence Community. (2020). https://www.intelligence.gov/images/AI/AI_Ethics_Framework_for_the_Intelligence_Community_1.0.pdf
- Athanassopoulos, E., & Voskoglou, M. G. (2020). A philosophical treatise on the connection of scientific reasoning with fuzzy logic. *Mathematics*, 8, 875.
- Banzhaf, W., Nordin, P., Keller, R., & Francone, F. (1998). *Genetic programming – An introduction*. Morgan Kaufmann.
- Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day* (1st ed.). ISTE.
- Bertsch McGrayne, S. (2012). *The theory that would not die*. Yale University Press.
- Bloom, B. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13(6), 4–16.
- Borji, V., & Voskoglou, M. (2016). Applying the APOS theory to study the student understanding of the polar coordinates. *American Journal of Educational Research*, 4, 1149–1156.
- Breazeal, C. (2002). *Designing sociable robots*. MIT Press.
- Brockman, J. (2015). *What do you think about machines that think?* <http://edge.org/response-detail/26871>
- Buckley, J. J., & Hayashi, Y. (1994). Fuzzy neural networks: A survey. *Fuzzy Sets and Systems*, 66, 1–13.
- Chatti, M. A. (2010). The LaaN theory. In *Personalization in technology enhanced learning: A social software perspective* (pp. 19–42). Shaker.
- Cherry, K. (2019). *History and key concepts of behavioral psychology*. <https://www.verywellmind.com/behavioral-psychology-4157183>
- Crawford, K. (1996). Vygotskian approaches in human development in the information era. *Educational Studies in Mathematics*, 31, 43–62.
- Das, S., Day, A., Pal, A., & Roy, N. (2015). Applications of artificial intelligence in machine learning. *International Journal of Computers and Applications*, 115, 31–41.
- Doabler, T., & Fien, H. (2013). Explicit mathematics instruction: What teachers can do for teaching students with mathematics difficulties. *Intervention in School and Clinic*, 48, 276–285.
- Dowens, S. (2005). *An introduction to connective knowledge*. www.downes.ca/cgi-bin/page.cgi?post=33034
- Dubois, D., & Prade, H. (2001). Possibility theory, probability theory and multiple-valued logics: A clarification. *Annals of the Mathematics and Artificial Intelligence*, 32, 35–66.
- Fisher, C. (2007). *Teacher as network administrator*. http://remoteaccess.typepad.com/remote_access/files/teacher_as_network_admin.pdf
- Goyal, S. (2012). E-learning: Future of education. *Journal of Education and Learning*, 6, 239–242.
- Hee, J. W., Lee, E. J., Park, H. J., Chang, A. K., & Kim, M. J. (2013). Use of the 5E learning cycle model combined with problem-based learning for fundamentals of a nursing course. *Journal of Nursing Education*, 52(12), 681–689.
- Ibrahim, D. (2016). An overview of soft computing. *Procedia Computer Science*, 102, 34–38.
- Jang, J.-S. (1997). ANFIS: Adaptive, network-based fuzzy inference system. *IEEE Transactions on Systems, Man and Cybernetics*, 23(3), 665–685.
- Jaworski, B. (2006). Theory and practice in mathematics teaching development: Critical inquiry as a mode of learning in teaching. *Journal of Mathematics Teacher Education*, 9, 187–211.
- Jaynes, E. T. (2011). *Probability theory: The logic of science* (8th ed.). Cambridge University Press. (First published, 2003).
- Jeffreys, H. (1973). *Scientific inference* (3d ed.). Cambridge University Press.
- Kastranis, A. (2019). *Artificial intelligence for people and business*. O'Reilly Media.

- Kazimoglu, C., Kiernan, M., Bacon, L., & MacKinnon, L. (2011). Understanding computational thinking before programming: Developing guidelines for the design of games to learn introductory programming through game-play. *International Journal of Game-Based Learning, 1*, 30–52.
- Klir, G. J., & Folger, T. A. (1988). *Fuzzy sets, uncertainty and information*. Prentice-Hall.
- Kolodner, J. L. (1991). Improving human decision making through case-based decision aiding. *AI Magazine, 52*–69.
- Kosko, B. (1990). Fuzziness Vs probability. *International Journal of General Systems, 17*(2–3), 211–240.
- Lage, M. G., Platt, G. J., & Tregla, M. (2000). Inverting the classroom: A gateway to create an inclusive learning environment. *The Journal of Economic Education, 31*, 30–43.
- Lee, J., Lim, C., & Kim, H. (2017). Development of an instructional design model for flipped learning in higher education. *Educational Technology Research and Development, 65*, 427–453.
- Lejewski, C. (1967). Jan Lukasiewicz. In *Encyclopedia of philosophy* (Vol. 5, pp. 104–107). Free Press.
- Liu, J., & Wang, L. (2010). *Computational thinking in discrete mathematics*. In Proceedings of the IEEE 2nd international workshop on education technology and computer science, Wuhan, pp. 413–416.
- Mamdani, E. H., & Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. *International Journal of Man-Machine Studies, 7*(1), 1–13.
- McKinley, J. (2015). Critical argument and writer identity: Social constructivism as a theoretical framework for EFL academic writing. *Critical Inquiry in Language Studies, 12*, 184–207.
- Mergel, B. (1998). *Instructional design and learning theories*. <http://www.usask.ca/education/coursework/802papers/mergel/brenda.htm>
- Miller, P. H. (2011). Piaget's theory: Past, present, and future. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development* (pp. 649–672). Wiley Blackwell.
- Mitchell, M. (2019). *Artificial intelligence: A guide for thinking humans*. Parrar, Straus and Gtraux.
- Papilinski, A. P. (2005). *Basic concepts of neural networks and fuzzy logic systems*. <https://www.cic.ipn.mx/~pescamilla/ContInt/Papilinski2005.pdf>
- Pasick, A. (2023). *Artificial intelligence glossary: Neural networks and other terms explained*. <https://www.nytimes.com/article/ai-artificial-intelligence-glossary.html>
- Payne Carter, S., Greenberg, K., & Walter, M. (2016). *The impact of academic usage in academic performance: Evidence from a randomized trial on the US Military Academy* (Working paper #2016.02). US Military Academy. <https://seii.mit.edu/research/study/the-impact-of-computer-usage-on-academic-performance-evidence-from-a-randomized-trial-at-the-united-states-military-academy>
- Rifkin, J. (2014). *The zero marginal cost society: The internet of things, the collaborative commons and the eclipse of capitalism*. St. Martin's Press.
- Rocha, L. M. (1998). *Selected self-organization and the semiotics of evolutionary systems*. <http://informatics.indiana.edu/rocha/ises.html>
- Salem, A. B. M., & Parusheva, S. (2018). Exploiting the knowledge engineering paradigms for designing smart learning systems. *Eastern – European Journal of Enterprise Technology, 2*, 38–44.
- Schwab, K. (2016). *The fourth industrial revolution*. Crown Publishing Group.
- Seely Brown, J. (2006). *Learning in the digital age (21st century)*. Ohio Digital Commons for Education. <http://www.olin.org/conferences/ODCE2006/papers/jsb-2006ODCE.pdf>
- Siemens, G. (2005). Connectivism: A learning theory for a digital age. *International Journal of Instructional Technology and Distance Learning, 2*(1), 1–9.
- Siemens, G. (2008). *Learning and knowledge in networks: Changing roles for educators and designers*. Presented in ITFORUM for Discussion. <https://www.semanticscholar.org>
- Sugeno, M. (1985). *Industrial applications of fuzzy control*. Elsevier Science.
- Taber, K. S. (2011). Chapter 2: Constructivism as educational theory: Contingency in learning, and optimally guided instruction. In J. Hassaskhah (Ed.), *Educational theory* (pp. 39–61). Nova Science Publishers.

- Taipale, S., Vincent, J., Sapio, B., Lugano, G., & Fortunati, L. (2015). Introduction: Situating the human in social robots. In J. Vincent, S. Taipale, B. Sapio, G. Lugano, & L. Fortunati (Eds.), *Social robots from a human perspective* (pp. 1–17). Springer.
- Tankelevience, L., & Damasevicius, F. (2009). Characteristics for domain ontologies for web based learning and their applications for quality evaluation. *Informatics in Education*, 8, 131–152.
- Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., Kaiser, L., & Polosukhin, I. (2017). *Attention is all you need*. arXiv: 1706.03762.
- Verhagen, P. (2010). *Connectivism: A new learning theory?* <http://elearning.surf.nl/e-learning/english/3793>
- Voskoglou, M. (2005). *The application-oriented teaching of mathematics*. In Proceedings of the International Conference on Mathematics Education, Svishtov, Bulgaria, pp. 85–90.
- Voskoglou, M. (2008). Case-based reasoning: A recent theory for problem-solving and learning in computers and people. In *Communications in computer and information science* (Vol. 19, pp. 314–319). Springer.
- Voskoglou, M. (2010). Problem-solving as a component of the constructivist view of learning. *The Journal of Educational Research*, 4, 93–112.
- Voskoglou, M. (2013). An application of the APOS/ACE approach in teaching the irrational numbers. *Journal of Mathematical Sciences and Mathematics Education*, 8, 30–47.
- Voskoglou, M. G. R. (2019a). Communities of practice for teaching and learning mathematics. *American Journal of Educational Research*, 7(6), 186–191.
- Voskoglou, M. G. R. (2019b). An application of the “5 E’s” instructional treatment for teaching the concept of the fuzzy set. *Sumerianz Journal of Education, Linguistics and Literature*, 2, 73–76.
- Voskoglou, M. G. (2019c). Methods for assessing human-machine performance under fuzzy conditions. *Mathematics*, 7, 230.
- Voskoglou, M. G. (2019d). Generalizations of fuzzy sets and related theories. In M. Voskoglou (Ed.), *An essential guide to fuzzy systems* (pp. 345–352). Nova Science Publishers.
- Voskoglou, M. G. (2020a). Fuzzy control in cyber-physical systems. *International Journal of Cyber-Physical Systems*, 2(2), 46–58.
- Voskoglou, M. (2020b). Thoughts for the future education in the era of the fourth industrial revolution. *American Journal of Educational Research*, 8(4), 214–220.
- Voskoglou, M. G., & Buckley, S. (2012). Problem solving and computers in a learning environment. *Egyptian Computer Science Journal*, 36, 28–46.
- Voskoglou, M. G., & Salem, A. B. M. (2014). *Analogy based and case based reasoning: Two sides of the same coin*. arXiv: 1405.7567.
- Voskoglou, M. G., & Salem, A.-B. M. (2020). Benefits and limitations of the artificial with respect to the traditional learning of mathematics. *Mathematics*, 8, 611.
- Wallace, B., Ross, A., Davies, J. B., & Anderson, T. (2007). *The mind, the body and the world: Psychology after cognitivism*. Academic. Imprint.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.
- Wing, J. M. (2006). Computational thinking. *Commun. ACM (Assoc. Comput. Mach.)*, 49, 33–35.
- Yang, X. (2019). Accelerated move to AI in China, *ECNU Rev. Educ.*, 2, 347–352.
- Zadeh, L. A. (1965). Fuzzy Sets, *Inf. Control*, 8, 338–353.
- Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision processes. *IEEE Trans. Syst. Man Cybern.*, 3, 28–44.
- Zadeh, L. A. (1978). Fuzzy Sets as a basis for a theory of possibility, *Fuzzy Sets Syst.*, 1, 3–28.
- Zadeh, L. A. (1994). Fuzzy logic, neural networks and soft computing, *Communications of the ACM*, 37(3), 77–84.

Chapter 7

Play, Code, Learn: Fostering Computational Thinking in Primary Aged Learners Through Interactive Play



Sarah Washbrooke and Nasser Giacaman

Introduction

In recent years, there has been a significant shift in the educational landscape, with computer science emerging as a compulsory subject in schools worldwide (Passey, 2017, Webb et al., 2017). As society becomes increasingly digital, equipping young minds with essential computational skills has emerged as a priority. This book chapter aims to introduce an innovative educational tool, known as ‘Play Code Learn’, that seamlessly integrates augmented reality (AR), mobile app technology, and the power of play to foster the learning of computer science concepts among children.

Play has long been recognised as a powerful vehicle for learning (Lynch, 2015). It engages children’s natural curiosity, fosters creativity, and promotes the development of essential cognitive, social, and emotional skills (Fisher et al., 2012). By infusing play into computer science education, we can tap into its transformative potential to facilitate deep understanding and long-term knowledge retention.

At the same time, it is also crucial to ensure that computer science instruction follows curricula guidelines (Falkner et al., 2019). The evolving landscape of computer science curricula presents a complex web of concepts, skills, and learning outcomes (Sentance & Csizmadia, 2017). Educators face the challenge of designing

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meaningful and effective lessons that align with these curricula while addressing the diverse needs of their students (Falkner et al., 2019).

To support teachers in this endeavour, it is essential to provide them with comprehensive resources that include curricula-aligned activities targeting specific learning outcomes. By doing so, we empower educators with the tools they need to guide their students through the intricacies of computer science education, fostering a robust understanding of foundational concepts (Sentance & Csizmadia, 2017).

Recognising the significance of both play and curricula alignment, the educational STEM kit, named 'Play Code Learn', combines these two critical components. Play Code Learn (PCL) offers a carefully crafted STEM kit that allows students to embark on playful, hands-on activities aligned with the curricula. By immersing children in the physical exploration of computer science concepts, the kit lays a solid foundation of computer science understanding before transitioning to digital tools.

An essential aspect of PCL lies in its 'unplugged' activities. These unplugged experiences enable learners to engage with computer science without the need for computers or mobile devices (Bell et al., 2012). By incorporating physical components, students develop an intuitive grasp of abstract concepts, fostering their computational thinking (CT) skills while promoting collaboration and creativity.

The integration of AR technology serves as a powerful complement to the physical kit, elevating the learning experience to new heights. The use of AR enhances PCL by overlaying computer-generated virtual elements onto the real world, providing an immersive and interactive environment for students to explore computer science concepts. Through AR simulations, abstract ideas become tangible, enabling learners to visualise algorithms, data structures, and coding principles in captivating and relatable ways.

The incorporation of AR not only amplifies engagement but also brings forth additional benefits. AR enhances visualisation, making complex concepts more accessible and understandable (Wu et al., 2013). It facilitates personalised learning experiences, adapting to individual student needs and providing real-time feedback (Angelopoulou et al., 2012). Moreover, AR promotes collaboration and communication skills, preparing students for the collaborative demands of the digital era (Phon et al., 2014).

This chapter will explore the unique benefits of PCL, which seamlessly integrates the power of play, unplugged activities, and augmented reality to support computer science education for primary aged students. We will delve into the significance of aligning instructional resources with curricula guidelines, empowering teachers to deliver effective and meaningful lessons. Furthermore, we will investigate the impact of PCL on learners by examining pilot studies and analysing the results, shedding light on its efficacy in fostering knowledge retention, collaboration, and meaningful learning experiences.

Literature Review

Unplugged Computing

The ‘unplugged’ approach in computer science education provides several key benefits. It allows for a broader coverage of computer science topics within limited time constraints while eliminating the need for extensive computer setup and resources—making it more accessible and cost-effective (Huang & Looi, 2021). Unplugged also challenges the notion that computer science is solely about programming and therefore showcases its wider applications. This helps dispel misconceptions about computer science and attracts a diverse range of students (Bell et al., 2012).

A recent literature review revealed that both plugged and unplugged applications enhance children’s CT and programming skills in early childhood education, but unplugged applications tend to be more effective as they provide concrete experiences (Bati, 2022). It was found that age plays a role, with older children benefiting more from plugged-in applications (Bati, 2022). Physical experiences tend to be more effective for younger children (Bati, 2022).

AR in Education

Chen et al. (2017) reviewed 55 papers on augmented reality (AR) in education, focusing on sample groups, contributing countries, subject domains, types of AR, research methods, and effectiveness. The studies identified learning gains, motivation, and positive attitudes as advantages of using AR in educational settings. Some of the future trends identified include the consideration of individual interaction and more interactive strategies.

AR in educational settings offers several affordances, as it provides a sense of presence and immersion that fosters engagement. It also allows for the visualisation of otherwise invisible concepts, therefore bridging the gap between formal and informal learning. But to fully leverage these affordances, the alignment of AR with instructional approaches (e.g. game-based learning) is crucial (Wu et al., 2013).

In computer science education, the integration of AR and tangible user interfaces offers exciting possibilities for enhancing learning of programming and other computer science topics. Efforts have included the development of collaborative AR environments that facilitate collaborative programming, code visualisation, and code debugging. These techniques have shown potential to engage students and deepen their understanding of complex computer science concepts (Resnyansky et al., 2018).

Pedagogical Models

This section outlines the key pedagogical models guiding the design of the PCL STEM kits.

Play-based learning (PBL) combines play and academics to promote children's development and learning. It emphasises experiences that allow children to learn while exploring, making mistakes, and constructing knowledge by interacting with their environment (Taylor & Boyer, 2020). While PBL is a topic of interest among early childhood and primary education, there is a need for tailored professional development in order to support teachers in engaging with play while scaffolding social and academic skills (Bubikova-Moan et al., 2019). Enhancing play-based learning with interactive devices and technologies has shown to improve student achievement, motivation, and collaboration among children (Taylor & Boyer, 2020).

Game-based learning (GBL) refers to gameplay that mixes learning outcomes, which can involve both digital and non-digital games. The process of GBL aims to balance subject matter with engaging gameplay (Plass et al., 2015). The rapidly evolving digital landscape, including video and computer games, provides unique opportunities for engaging learners with digital game-based learning. Digital games offer immersive and interactive environments that promote active learning and problem-solving (Acquah & Katz, 2020). Despite initial misconceptions, digital game-based learning in modern educational settings has shown great impact and continues to grow (Sailer & Homner, 2020).

Constructive alignment is a pedagogical approach to enhance student learning by emphasising the alignment between intended learning outcomes, learning activities, and assessments (Biggs, 1996). Its application has shown to result in clearer learning goals, higher student engagement, as well as deeper understanding and meaningful learning (Jervis & Jervis, 2005). Applying constructive alignment has shown to create a supportive environment that encourages learner autonomy, improves students' critical thinking, and assists in transferring knowledge and skills to real-world contexts (Kandlbinder, 2014).

The *Substitution, Augmentation, Modification, Redefinition* (SAMR) model offers a structured framework for integrating digital technology in education (Puentedura, 2006). At the Substitution level, digital technology acts as a direct substitute for traditional (analogue) tools, while Augmentation brings enhancements to teaching and learning practices. Modification takes digital technology integration further by allowing for meaningful task redesign, while Redefinition represents the highest level where digital technologies enable the creation of new and innovative learning experiences (Romrell, et al., 2014). By following the SAMR model, educators can enhance student engagement, foster critical thinking skills, and promote collaboration, leading to improved learning outcomes (Crompton & Burke, 2020).

Conceptual Frameworks and Play Code Learn

Play Code Learn is a new educational teaching resource for primary aged learners by ByteEd, a New Zealand-based educational company. ByteEd focuses on the design and development of professional learning and teaching resources that utilise and teach virtual reality (VR) and AR concepts, skills, and techniques.

The dinosaur series of kits, within PCL, have been developed using the latest computer science methodology and educational pedagogies discussed previously in this chapter, with the intention to engage all learners with CT, moving them from being ‘users’ of digital tools to being ‘creators’ with digital technologies following the SAMR model approach (Puentedura, 2006), thus enabling higher retention of conceptual understanding by leveraging digital in authentic ways (Fullen & Langworthy, 2014).

PCL kits focus on building self-efficacy for learning, increasing students understanding of technological vocabulary and computer science concepts through ‘reachable’ unplugged-to-digital learning experiences (Bell & Vahrenhold, 2018; Curzan et al., 2014; Hermans & Aivaloglou, 2017; Munasinghe et al., 2023). The unplugged style of teaching has been seen as a reassuring and effective teaching approach for teachers to manage in their own classes. Unplugged activities are also used to train teachers, by reducing the fear that some teachers have around programming, by introducing educators slowly and effectively to the main concepts of CT and computer science (Curzan et al., 2014). Unplugged activities therefore not only support students’ learning but also provide a comfortable, safe, and informative way to train teachers to understand overarching computer science concepts as ‘unplugged activities make for an inspiring and fun session for teachers that they also find useful, interesting and confidence building’ (Curzan et al., 2014, p. 92.).

When unplugged activities are taking place, this shares some of the constructivist intent for learning, for example, teaching abstract concepts with concrete, constructive and kinaesthetic activities, while also enabling students to (re)construct knowledge for themselves (Bell & Lodi, 2019). Vygotsky’s social theory of constructivism (Vygotsky, 1979) is one theoretical model students work through when learning about CT by undertaking unplugged activities. By working on collaborative activities to solve problems, employing cognitive strategies to accomplish tasks, and using self-reflection and evaluation, students are enabled to work in their proximal development zones (the space between what a learner can do without assistance and what a learner can do with adult guidance or in collaboration with more capable peers where new concepts are developed) by building metacognitive awareness (Markandan, et al., 2022).

The overarching concept of an integrated STEM approach provided a foundation for the development of the Play Code Learn kits. With integrated curriculum approaches among STEM subjects having positive effects on students’ achievement (Becker & Park, 2011), especially with younger learners (Becker & Park, 2011., Kaleci & Korkmaz, 2018.), the first Play Code Learn kit was aimed at students aged

4–8 years of age to give them a baseline understanding of computer science while also integrating curriculum areas of mathematics and science.

Through hands-on STEM learning experiences, all learners (students and teachers) develop problem-solving skills and effective communication and deepen STEM literacy. The opportunity to interweave other curriculum subject content provides ‘real-life’ uses for principles and concepts helping students to understand why this learning is important. The use of physical STEM learning activities improves an individuals’ attitude towards science, mathematics, and technology in a positive way (Baran et al., 2015; Jackson & Mohr-Schroeder, 2018; Kaleci & Korkmaz, 2018).

PCL kits have been designed to include the following key ideas, developed from current research and discussion with experienced educators:

- Support *progressive* learning that reinforces prior knowledge.
- Engage and build a *growth mindset* (Dweck, 2007).
- Deepen technological literacy.
- Deepen learning with *critical thinking*.
- Promote logical thinking and problem-solving abilities.
- Student agency or adult/teacher led.
- *Integrate* and weave other *curriculum* subjects.
- Enable and motivate different abilities to learn.
- Use current methodology and practices in teaching.
- Connect knowledge with *real-life experiences*.
- Inclusive and educational for all.
- Future focused, enabling ‘learning to learn’ skills and techniques.

Children need to develop deep conceptual understanding when learning, which allows them to connect concepts and skills, apply their knowledge to different situations, and spark new ideas (Frey et al., 2016; Winthrop & McGivney, 2016). To be future-focused learners, teachers need to support students to be happy, healthy, thinking, caring, and social children who will become collaborative, creative, competent, and responsible citizens tomorrow (Golinkoff & Hirsh-Pasek, 2016). To enable and develop these ‘soft skills’ (also known as employability skills) and playful learning characteristics (Zosh et al., 2018) (joyful, meaningful, actively engaging, iterative, and social interaction), the PCL kits utilise a play-based and game-based learning approach to encourage collaborative learning in a fun and authentic way.

In designing the PCL kits, computer science and digital technologies curricula from across the world were reviewed. Initial digital learning progressions were developed based upon the revision to the technology learning area in the New Zealand Curriculum (NZC). In 2017, the technology learning area was modified to integrate the two technology areas: computational thinking and designing and developing digital outcomes (Ministry of Education, 2007). With technology being a compulsory learning area for Year 1 to Year 10 (ages 5–15), teachers and students need to upskill and take part in learning activities to develop understanding and knowledge of digital technologies. After reviewing the changes to NZC and

comparing criteria with other computer science standards globally, the following key concepts were identified for the first PCL kit to cover:

- Algorithmic thinking.
- Sequential instructions (write, give, and follow).
- Algorithms and programs.
- Spotting errors and debugging.
- Decomposition.
- Using digital tools (hardware and software).
- Innovative technologies.

Progression of learning, based on global and NZC curricula, continues with the next two PCL dinosaur kits. *Dinosaur Loops* reinforces Dinosaur Steps knowledge by introducing iteration, efficiency, and pattern recognition. This then leads to *Dinosaur Commands*, which uses a game-based approach to develop understanding of events, conditional statements, variables, and functions alongside all CT concepts.

All Play Code Learn Dinosaur kits use a three-pillar approach to teaching and learning:

Unplugged, hands-on, physical kit, enabling students to learn key terminology and practice concepts through a play-based and game-based approach.

ByteEd App, available on Android or iOS, moves learning from a physical space to an online environment. Students learn to convert algorithms to computer programs with a drag and drop block-based coding system in an AR environment.

Online Teaching Portal, with access to many pre-prepared teaching resources to support learning in the classroom including a ten-lesson teaching module that uses further unplugged activities to introduce key concepts before encouraging practice of these concepts with the kit and app. The teaching module is well scaffolded to support beginner teachers to coding and supports a range of students through differentiated learning activities and formative assessment linked to curricula.

Dinosaur Steps STEM Kit

The first kit in the PCL dinosaur series is Dinosaur Steps. Students start their learning journey by using computational thinking concepts to make a predesigned dinosaur land jigsaw puzzle (introducing decomposition, algorithms, abstraction, logical thinking, and pattern recognition).

Once the puzzle is made, students then work through the instructional booklet and the algorithm challenges on their own (Fig. 7.1) and then in groups, or the teacher can lead whole class learning by using the activities and teaching module from the online teaching portal.



Fig. 7.1 Creating algorithms after plotting paths on the dinosaur land jigsaw

Essentially, with the hands-on kit, students develop an understanding of simple algorithmic thinking: plotting logical paths, thinking about order, sequence, and debugging while exploring all CT concepts with a focus on decomposition.

The ByteEd App enables learners to deepen algorithmic thinking by converting unplugged algorithms into computer programs through digital coding (demonstrated in Fig. 7.2).

While the app encourages students to program digitally, it is not a sedentary activity like other coding approaches. By using AR, students can view the dinosaur land and the dinosaurs from different angles. This can actively encourage learners to move into other learning environments, for example, placing the dinosaurs in more natural habitats to view them in AR.

Fig. 7.2 Using the ByteEd App to learn about AR and programming



Play Code Learn: Dinosaur Steps Pilot Project

Methodologies

A mixed-methods research (MMR) approach was adopted as the research methodology to study the impact on learning, knowledge retention, and motivation of students and teachers with PCL Dinosaur Steps. With pragmatism being an underpinning

philosophical driver for MMR (Feilzer, 2010; Hall, 2013; McCrudden et al., 2019), it enabled the researchers to explore societal issues by taking action in an intelligent way (*intelligent action*) (Hall, 2013).

Pragmatically, MMR was used with the understanding that the methods were utilised intelligently to attend to a specific problem and to provide information that will help to make evaluative judgements (Hall, 2013). MMR was selected as an approach because it ‘allows for both the scientific objective rigour of quantitative approaches and the contextual, interrelational exploration offered by qualitative approaches’ (Frost & Shaw, 2015, p. 383). The qualitative strand was used to elaborate, enhance, and explain some of the findings of interest from the quantitative strand (Creswell & Plano Clark, 2018).

Aim

Specifically, this chapter addresses the following research question:

How have ByteEd’s Play Code Learn (PCL): Dinosaur Steps teaching resources impacted student learning and retention of knowledge in the learning area of computer science and computational thinking?

Participants

This research was conducted during Term 4, 2022, and was based in two classrooms in Aotearoa New Zealand. The participants’ details, background, and experience are outlined in Table 7.1.

The original intent of the project was for teachers to work through Dinosaur Steps ten pre-prepared lessons in the teaching portal, introducing computational thinking concepts and digital technologies. Unfortunately, due to time limitations and an increase of school activities in class time during the final term of the school year, both classes only managed to teach content from five lessons in the teaching

Table 7.1 Participants’ details and background

Pseudonym	Class details	Background/experience
Class A	Combined Y3–4 class (age 7–9) 22 students Urban co-educational school	Teacher proficient in teaching digital technologies Class had some prior experience with computational concepts earlier in the year
Class B	Year 3 (age 7–8) 15 students Urban co-educational school	Teacher had no prior experience teaching digital technologies at all Class had no prior knowledge of computational thinking concepts at all

Table 7.2 Lesson coverage from Dinosaur Steps teaching module

Learning	Class A	Class B
Lesson 1 What is CT?	✓	✓
Lesson 2 Sequence and algorithms	✓	✓
Lesson 3 Debugging	✓	✓
Lesson 4 Decomposition	✓	✓
Lesson 5 Pattern recognition	✓	X
Lesson 6 Abstraction	X	✓
Lesson 7 Logical thinking	X	X
Lesson 8 Augmented reality (AR)	X	X
Lesson 9 Algorithms to programming	X	X
Lesson 10 CT recap	X	X

module. As shown in Table 7.2, learning that did take place introduced key CT concepts using unplugged activities and the hands-on practical Dinosaur Steps kits. However, neither of the classes got to the stage of exploring AR and programming by using the ByteEd app.

Data Collection and Analysis

The researchers used a convergent MMR design approach to collecting data, with both qualitative and quantitative methods being collected concurrently (Alansari et al., 2023). With a focus on knowledge retention, we gathered data from the students using a Google form both prior to learning with the PCL kits (pretest) and after completing their lessons (posttest). The aim was to collect data from all students, by sampling a range of abilities and attitudes in a systematic and consistent way (Meissel & Brown, 2023).

Questions for the tests were developed after completing analysis of many international computer science curricula to identify the common learning criteria for computational thinking and computer science for students aged 4–9. Figure 7.3 demonstrates the analysis of computer science curricula.

To provide a holistic view of learning, we placed value in building respectful relationships with the teachers who were implementing the project. With ‘peoples perspectives at the heart of the research there will be multiple dimensions and

CT skills & knowledge	Total	Curriculum										Key coverage in the project test 1 = Most important		
		NZ CT-P01 (Y1 0-2)	NZ CT-P02 (Y1 2-6)	Australia (Y1 0-2)	Australia (Y1 2-4)	UK National Curriculum KS1 (Y1 1-2)	UK National Curriculum KS2 (Y1 3-4)	Cambridge International Stage 1	Cambridge International Stage 2	US CS Standards CS19A K-2	US CS Standards CS19A 3-5		Massachusetts K1-2	Massachusetts K3-5
Decomposition	5													5
Unplugged algorithms	12													1
Create & follow step by step instructions	12													1
Algorithmic thinking	2													
Give instructions	2													1
Identify errors	6													3
Debugging	7													3
Create programs	9													2
Outputs	2													
Sequencing	6													
Play & integrated learning	2													1
Spotting patterns	2													
Use abstraction to define problems	2													
Branching, conditionals	3													
User inputs	2													
Logical reasoning	3													
Predict behaviour of programs	2													
Selection	1													
Repetition (loops, iteration)	4													
Variables	1													
Hardware & software	6													4
Events	1													
Abstraction	2													
Commands	2													
More than one solution exists	1													
Starting values	1													

Fig. 7.3 Analysis of computer science curricula to identify key concepts for the teaching of computational thinking

perspectives’ (Doyle & Loveridge, 2023, p. 65.), and we needed to ensure conversations that were conducive to the sharing of teachers’ and students’ personal experiences (Luttrell, 2010).

We wanted to learn about the impact of learning and how the teachers saw the kits as an educational resource for learning based on their own experiences and observations in the classrooms. The stories of the teachers were collected in various forms throughout the project and included informal, open conversations with researchers, recording evidence with photographs and video, gathering feedback on each lesson during the teaching of the module with student self-reflection exit statements and recording their observations of students, creating overall teacher judgements (OTJ’s) on curriculum knowledge, and providing final feedback through open interviews (online and face-to-face) and written documentation.

Teachers’ narratives were also supported with researcher observations on some of the lessons taught through the module. Throughout all qualitative methods, we were cognisant of participants’ apparent emotions, tone, and non-verbal communication (Anderson, 2010).

Data analysis followed a sequential process whereby the data was collected and findings were recorded and coded (Miles, et al., 2020). The stages of data analysis occurred concurrently with data collection (Cohen, et al., 2018). Key themes were identified from the research question and organised according to the understanding and knowledge of CT concepts and motivation for learning about computer science using the different teaching methodologies offered.

Analysis and reporting of findings represent both *etic* and *emic* analysis. An *etic* perspective can explore external factors that are not necessarily salient to the participants, and the *emic* perspective considers the insider’s point of view—primarily the students and teachers (Morris et al., 1999).

Dinosaur Steps Pilot Project 2022: Results and Initial Analysis

Findings

The key findings from this research project are organised according to the main concepts from computer science curricula as shown in Fig. 7.3. These ideas include:

- Algorithmic thinking (sequence, logical order, instructions).
- Identifying errors (bugs) and debugging.
- Computational thinking concepts.

Algorithmic Thinking

What Is an Algorithm? This is an area that both schools identified as having partially taught. *Lesson 2: Sequential Instructions and Algorithms* introduced the concept of an algorithm; however, reinforcement of algorithms in later lessons including *Lesson 9: Algorithms to Programs* was not taught in the pilot due to lack of time in the term. The posttest results for this reflect the students' current understanding of what an algorithm is.

Many students understood that an algorithm was a form of step-by-step instructions to complete a task, as demonstrated in the whiteboard discussion from Class A in Fig. 7.4, and could select some of the examples in the test. However, students did not select *all* of the examples required in the test or were sidetracked by other choice options (e.g. musical instrument as it has a 'rhythm').

The following graphs from Class B's pretest and posttest demonstrate these findings.

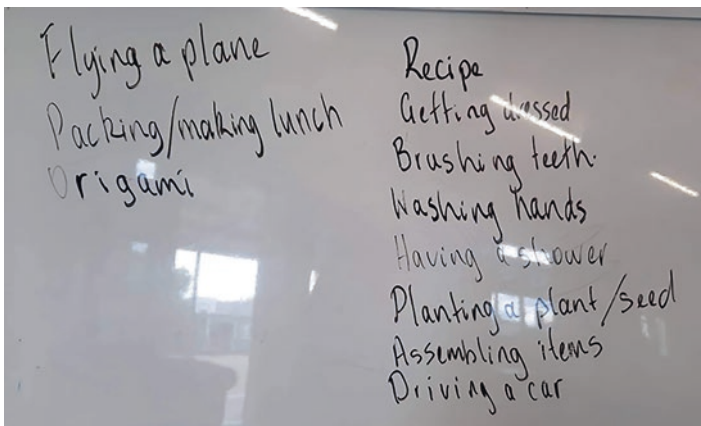


Fig. 7.4 List of 'real-life' algorithms created through class discussion in Class A

Pretest: Many students had some of the correct ideas but did not recognise all the correct answers, as demonstrated in Fig. 7.5.

Posttest: Fig. 7.6 demonstrates students were able to identify different types of algorithms, but once again each student missed some of the correct choices or were confused with the concept of ‘rhythm’:

From these results and observations, we can see that while students understood that a wide variety of processes could be an algorithm, by the end of the pilot they still could not confidently choose all examples of algorithms. This may be due to the teaching in the classroom not being complete or a misunderstanding of terminology (e.g. rhythm and algorithm) in relation to some of the options given in the tests.

Logical Sequencing Prior to classroom learning using the Dinosaur Steps kits, students were asked to put an everyday task into a logical order or series of steps (e.g. getting dressed, cleaning teeth). In the pretest, students had 73% of steps in the correct order. By the end of the learning, this had jumped to 92% in the posttest of students having the correct sequential order.

Reading Algorithms In the tests, students were asked to select the correct algorithm with the Dinosaur Steps kits to enable Explorer Ed to move from a fixed start position to a predetermined finish position. Both classes demonstrated a better understanding in this area when tested, with Class A students moving from 73% correct to 100% correct, while Class B increased from 60% correct to 92% correct.

This improvement for logical sequencing and reading algorithms coincided with the teaching of lessons 2–6 in the teaching module. In all of these lessons, students developed understanding of algorithms through the plotting of logical paths, writing algorithms, and testing the sequence of the instructions (Fig. 7.7). Students had lots of opportunities to practise writing logical algorithms and trialling them for success.

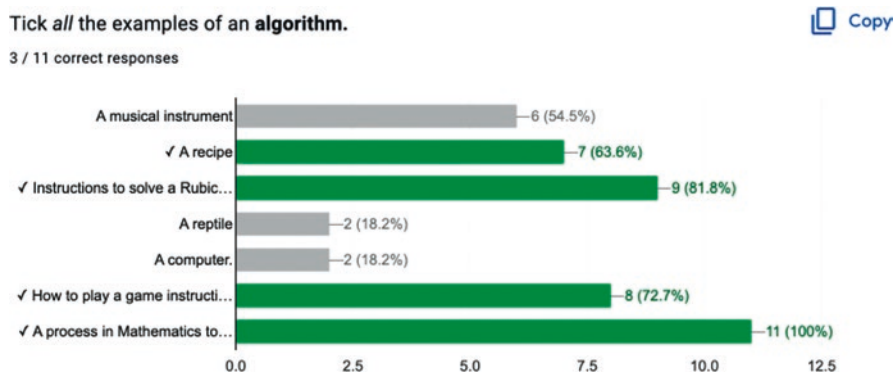


Fig. 7.5 Class B pretest raw results where students needed to select all the correct examples of an algorithm

Tick *all* the examples of an algorithm.



5 / 13 correct responses

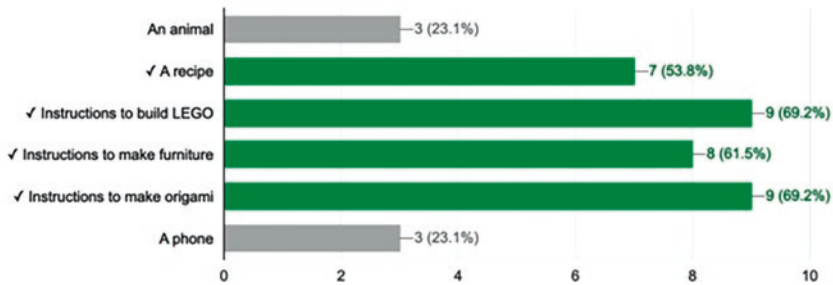


Fig. 7.6 Class B posttest raw results where students needed to select all the correct examples of an algorithm once again

Identifying Errors (Bugs) and Debugging

Spotting Bugs In this test question, students needed to show patience and care when counting the number of ‘bugs’ (ladybird images) they saw in a picture. Both classes demonstrated an increase in correct answers, with Class A moving from 86% to 91% correct and Class B increasing from 87% correct to 100%.

Interestingly, at Class B, more students would check and recheck they had counted the number of bugs correctly before selecting their answer when completing the posttest as opposed to the pretest.

Spotting the Bug in an Algorithm Once again, students showed a growth in understanding when identifying errors and debugging when tested. In the pretest, 59% of students from Class A could spot the bug in the algorithm. In the posttest, this increased to 68%. Similarly, Class B’s results increased from 33% to 75% correct.

Teacher observation from Class A:

The discussion, excitement and total engagement was awesome. The students would find the bugs and even said, that the code was not the shortest and most efficient route to take.

Lesson 3 Debugging in the teaching module supported students with their increased understanding of bugs, errors, and debugging. Both classes taught this lesson, and Class B students even experienced an extra unplugged outdoor debugging scavenger hunt to introduce the terminology for learners, prior to looking for bugs in algorithms with the kits. The teaching module lessons after lesson 3 also reinforced concepts of bugs and debugging through further learning activities. From the test results and teacher observations, we can conclude that students were motivated to learn about this concept and could link to prior learning with the Dinosaur Steps kits.



Fig. 7.7 Class B students plotting paths prior to writing algorithms with the unplugged Dinosaur Steps kit

Computational Thinking Concepts

Decomposition Both classes demonstrated improvement with the understanding of decomposition in CT when tested. Many tasks and activities throughout the teaching module explored decomposition, and we can see the improvement of understanding in the test results—for example, Class B’s test results when students decomposed a ‘dance’ that Explorer Ed did into different actions. In the pretest, 47% of students correctly identified the number of moves, while in the posttest 83% of students deduced the correct answer.

Once more, Class B students would check and recheck they had counted the number of actions correctly before selecting their answer when completing the post-test as opposed to the pretest, demonstrating the ability to review and edit answers rather than just select the first number.

Pattern Recognition The support lesson for pattern recognition from the Dinosaur Steps teaching module was not taught in Class B; however, aspects of this had been covered in some of the other Dinosaur Steps teaching module lessons for both

classes. There were two parts to pattern recognition: spotting repeated patterns and spotting bugs in repeated patterns. When identifying the repeated pattern (Fig. 7.8), there was no clear change for Class A between the pretest and posttest. At both times, 20/22 students (91%) were able to spot the repeated pattern. However, in Class B, there was a shift in understanding moving from 93% correct to 100% correct. As this class had not been taught the pattern recognition lessons from the teaching module, the increase was potentially due to the reinforcement of pattern recognition through mathematics activities and quizzes that students were completing everyday as part of their classwork and their ability to transfer this skill from mathematics to computer science, or it could be due to ceiling effect when collecting data.

When spotting bugs in the test, both in patterns and in algorithms, it was easy to see the class that had been taught debugging using the Dinosaur Steps kit. Class A had been taught pattern recognition through Dinosaur Steps and saw an increase in understanding with 68% now demonstrating the correct answer as opposed to 41% in the pretest, while Class B which had not previously experienced debugging had a decrease in understanding (-7%).

Abstraction In the tests, students had to display their understanding of abstraction by selecting the correct/important attributes of the Dinosaur Steps dinosaurs. Once again, both classes showed an increase in understanding moving from 64% with correct answers to 83% (Class A) and 100% (Class B). It is interesting to note that the school that had the biggest increase of correct answers was Class B who had taught Lesson 6: Abstraction from the teaching module, while Class A did not teach the specific lesson and so did not show as much of an increase on understanding and knowledge retention.

Hardware and Programming

There were two questions in the tests that did not see a significant shift of knowledge and understanding with students' answers. These are linked to types of hardware and understanding what a computer program is. When selecting the correct types of digital hardware from selected images, the percentage of correct answers stayed the same for both classes at 36% and 33% between the pretest and posttest. Similarly, Class A had 59% of students select the correct answer when choosing the description of a computer program in both pretest and posttest; however, Class B saw an increase from 20% to 58%.

The lack of increase in knowledge retention and conceptual understanding could be explained by both classes not teaching the designated digital lessons to introduce hardware, programming, and AR—thus there was no increase in understanding. The one point of difference was the increase in Class B with understanding what a computer program is. In this case, it was observed that while programming knowledge



Fig. 7.8 Using the commands cards from the Dinosaur Steps kit to explore pattern recognition

content was not specifically taught in a designated lesson, it was referred to throughout some of the other lessons, especially when teaching about algorithms.

Participant Feedback

Student Feedback

As part of the lessons and testing, students were given the opportunity to express how they were feeling about the learning taking place. Students were given several choices, based on a Likert scale, including *happy*, *sad*, *excited*, *upset*, and *meh!* Analysis of the data from both pretests and posttests show 'positive' correlation

with no student at all selecting the ‘sad’ or ‘upset’ emotions. In fact, when totalling the data, 77% were ‘happy’ or ‘excited’ for the whole of the learning. This supports teacher and researcher observations of students during learning activities with lots of positive engagement with the kits and reflects the lesson evaluations of the students too.

Teacher Feedback

Class A, Teacher A:

Students who had been exposed to DT in previous year “flew” with the concepts and reinforced their prior knowledge. Students not previously exposed were engaged and wanting more. There were often “light bulb” moments when students would connect a concept of DT with the world around them. Often as teachers we see a standout group in different subjects; however boys and girls, high ability/low ability, they were all interested...and wanted to interact, learn and “play” with Ed and his Dinos.

Teacher A

Teacher A’s feedback demonstrates that all students were motivated to learn with the Dinosaur Step kits—no matter their prior experience, gender, and abilities (Fig. 7.9).

Dino Steps is an easy to follow and fun resource for all teachers. The integration of the Key Competencies and other Curriculum areas is a benefit being able to teach holistically.

Teacher A

The Aotearoa New Zealand Curriculum (NZC) identifies five key competencies that enable students to contribute as active members of their communities: thinking, using language, symbols and text, managing self, relating to others, and participating and contributing (MoE, 2007). Key competencies are seen as the ‘key to learning in every learning area’ (MoE, 2007, p. 12.). Teacher A identified the links between learning with Dinosaur Steps and NZC, from an attitude to action-based learning model through the weaving of key competencies in learning. They also identified that while Dinosaur Steps can support the technology curriculum, it also weaves in other curriculum subject content knowledge—for example, pattern recognition in mathematics—enabling students to transfer prior knowledge and deepen their understanding of concepts in a more holistic way.

I look forward to being able to continue to use this amazing resource within my classroom in the coming years and to seeing the students’ knowledge and understanding grow with their extended exposure. Thank you again for this opportunity. It has helped immensely to begin to rebuild my passion for being in the classroom.

Teacher A

Class B, Teacher B:

The kits were bright, engaging and intuitive for the children to use. In their “sand pit” time, they all put the jigsaw puzzle together, placed footprints on the boards to fit the squares, and

“drove” Explored Ed around, square by square, for instance. I would have liked to have been more rigorous in delivering the lessons than we were—didn’t start until week 2, skipped week 3, and only had one session a week thereafter.

Teacher B

While Teacher B highlighted the busy nature of Term 4, 2022, for her students, she also reinforced the use of the kits in the classroom with her students. Even though learners could be distracted with upcoming events (cricket, cultural week, school visitors), they enjoyed learning with the kits and were actively engaged in the lessons (Fig. 7.10), with unplugged activities and hands-on learning with Dinosaur Steps so much so that they had extra time with them in their ‘sand pit sessions’.



Fig. 7.9 Class A students engaged with learning using the Dinosaur Steps kits to write algorithms and debug errors

As a teacher I loved seeing how the Dino Steps lessons naturally supported a lot of key competency work I had focused on with the children, and how they integrated with their learning across the curriculum. The sequencing instructions lesson was a great example of this. The children could clearly see when their instructions had not been clear enough for another person to follow, or when they had not been listened to and followed properly (or both!). Many of the activities easily become independent activities to support children's literacy and maths during those times. "Make my pattern" or "Draw my Creature" were activities the children could choose from and much enjoyed after they had been introduced to them as a class during STEM time.

Teacher B

As with Teacher A, we can see that Teacher B made connections to the NZC, other curriculum subjects, and the technology learning area. Teaching with Dinosaur Steps appears to have other benefits alongside learning about CT and computer science. The teaching module extension activities appear to be another aspect that engaged and motivated students to continue their learning too.

If I had had more time I would have revisited each lesson a number of times, perhaps a main session, followed by mini practice sessions, as well as explicitly made links to other classroom routines (e.g. using an algorithm in a fitness rotation, and linking it to what we had done with the kits). The more familiarity I have with the programme the more I will be able to do this.

Teacher B

Limited time to teach with the kits seems to be a factor that Teacher B would like to improve in the future. Being able to start the programme at the beginning of the year and spread throughout the terms would aid the reinforcement of knowledge and concepts being taught.

Dinosaur Steps Pilot Project 2022: Discussion

Outcomes and Impact

Play Code Learn Dinosaur Steps kits are proving to be an engaging and fun STEM teaching resource that motivates students, aged 7–9, to learn about computational thinking and computer science concepts through an 'unplugged' approach. By using a hands-on, play-based model, students interact physically with educational resources and learn basic concepts quickly before utilising this new knowledge within teaching activities, prior to consolidating understanding through student-created challenges and optional extension learning opportunities. From student reflections, they tend to find using the kits to learn about digital technologies as a positive and exciting experience.

When paired alongside the teaching module and resources on the ByteEd teaching platform, teachers have observed a growth in NZC key competencies, soft skills such as collaboration, discussion, problem-solving and logical thinking skills, and



Fig. 7.10 Class B students learning about debugging

technical understanding and use of technological vocabulary. Teachers not only observed the development of computer science skills, but also the integration of concepts from other disciplines enabled students to grow in other curriculum subjects like literacy, arts, and other STEM subjects.

Even though both teachers only had the chance to teach five lessons (approximately 5 h of learning in the classroom), testing demonstrates a growth in computer science understanding and a positive shift with knowledge retention for computational thinking. This is particularly evident in algorithmic thinking, when creating and following sequential instructions, and identifying bugs and debugging.

Key Implications

The pilot project has demonstrated that the teaching methodology and use of Dinosaur Steps kits can have a significant impact on the knowledge retention and motivation to learn about computational thinking and computer science. With the lessons taught using unplugged, hands-on teaching activities to introduce concepts following a play-based learning model, both teachers noted the enthusiasm from students with this practical approach (unplugged-to-digital and play-based methodology) to learning about computing concepts. Other benefits included developing group working skills, learning to communicate with peers to work through problem solving, and deepening critical and logical thinking skills. Teachers also identified the STEM approach not only reinforced concepts from mathematics (e.g. spotting patterns, sequential number) and technology (vocabulary) but also wove into learning in other subject areas, for example, literacy-utilised sequential instructions, and in daily classroom routines, for example, following an algorithm as part of getting ready in the morning. Integration of subjects improves the ability of students when transferring knowledge to and from other curriculum subject areas.

The initial pilot with the two classes highlights the need for more research into the impact of the kits in relation to other areas of digital technologies, for example, understanding types of hardware, learning about how algorithms transition to computer programs, and whether the use of AR as an educational tool is effective.

Limitations of this study largely stem from time constraints that resulted in an incomplete coverage of the teaching module. In essence, the research has not seen the impact of using digital tools, through the ByteEd app and AR approach, to reinforce the conceptual knowledge gained from the unplugged learning tasks.

A challenge that may arise by extending the time is the loss of impetus to complete the project resulting in the teaching module still not being completed.

Another limitation was the pilot study only focussed on two classes of Year 3 and Year 4 students, as such we cannot judge the impact on learning with younger students in Year 1 to Year 3 despite the Dinosaur Steps kit being promoted as suitable for these levels. The challenge with running a pilot in classrooms at this younger age level would be the need for more support when gathering the pretest and posttest information (younger students will not be able to read and the set questions in the google form and so will need adult help to complete the test or have the pretesting and posttesting data discovered in a different way, e.g. as a class discussion with teacher support). Younger learners will also need to run through a 'foundation' programme to learn the basics, such as number sequence, directions (left right, forward, back), and simple commands (stop, finish, run) before working through the teaching module. While this will take extra time, ByteEd have made an ECE/absolute beginner teaching resource to support this challenge.

It would also be beneficial to research a deepened application of the SAMR model, enabling students to move from 'users' of digital tools to 'creators' with digital technologies, as an approach to deepen knowledge content and retention

through the use of and across all the Play Code Learn teaching resources (Dinosaur Steps, Loops & Commands).

In the Future

The PCL Dinosaur Steps pilot programme will be further developed and deepened. Based on teacher feedback, a longer time period must be dedicated to teach CT and CS with the Dinosaur Steps kit, looking at the shift of learning through an entire term to extend to across 1 year, enabling not only the teaching module to be taught but also allowing the chance for the teacher to revisit aspects and reinforce learning.

By extending the time allocation for the project, we can collect and analyse data focusing on the transition from unplugged to digital by completing the whole teaching module for Dinosaur Steps and thus introducing the ByteEd app to explore AR and programming.

In their feedback, teachers stated ‘the more familiarity I have with the programme the more I will be able to do this’. By continuing pilot projects with the first two teachers, we can observe if their prior knowledge of using the kits developed their own confidence and abilities in the teaching of computer science.

To enable rigour with research, the pilot programmes could expand by gaining teacher feedback and student data with other groups of learners, including early childhood education and new entrants (age 3–4), Year 1–Year 2 (age 5–6), and Year 3–4 (age 7–8) across a range of different school settings both in New Zealand and globally. With Dinosaur Steps being the first teaching kit in a series, the research could further deepen across the range of PCL teaching products, looking at the development of learning and how knowledge progresses over the intended year levels.

Conclusions

The Play Code Learn series of STEM kits have been developed using a wide variety of proven teaching pedagogies (STEM integration, SAMR model approach, play-based learning) and enable students to learn about computer science concepts via innovative methods (unplugged-to-digital approach, use of emerging technologies with programming and AR). Data analysis shows that the use of a play-based approach with engaging hands-on activities motivated students to learn in class and aided development of technological vocabulary and conceptual knowledge retention. Further benefits have become apparent through the trial, including the development of New Zealand Curriculum key competencies supporting students to develop as a learner and the opportunity for students to transfer knowledge and skills from other curriculum subject areas, in particular, the STEM field.

The PCL approach offers the opportunity for many students to learn computational thinking and computer science in an engaging way. Teaching with the kits can be scaled easily with small groups working together in class to support a school-wide approach. With the physical kit being reasonably priced (in comparison to similar digital teaching resources (e.g. robots), it is easily accessible to all no matter their socio-economic backgrounds. Teachers using the resource can choose to learn alongside their students or can take part in short teacher professional learning sessions (approximately 1–2 h in length) enabling teaching and learning to go ahead in a very short amount of time. With the integration of learning with all curriculum subjects and many international curricula, the PCL kits aim to be a sustainable learning resource for a long period of time.

While teachers and students gained confidence in computational thinking concepts, at this stage it is difficult to ascertain the impact of using augmented reality and the ByteEd App due to that part of the learning content not being delivered to students as part of the pilot programme. ByteEd is committed to running a more detailed impact project with schools and educators from across Aotearoa New Zealand and the world, this time ensuring teachers have more time to complete the entire teaching module to ensure students have the chance to reinforce their understanding from unplugged teaching and learning to a digital space.

References

- Acquah, E. O., & Katz, H. T. (2020). Digital game-based L2 learning outcomes for primary through high-school students: A systematic literature review. *Computers & Education*, *143*, 103667.
- Alansari, M., Webber, M., & Rubie-Davies, C. (2023). Mixed methods research: Theory, applications, and implications for working with diverse populations. In F. Meyer & K. Meissel (Eds.), *Research methods for education and the social disciplines in Aotearoa New Zealand* (pp. 98–112). NZCER Press.
- Anderson, C. (2010). Presenting and evaluating qualitative research. *American Journal of Pharmaceutical Education*, *74*(8), 141. <https://doi.org/10.5688/aj7408141>. Retrieved from: <https://www.ajpe.org/content/74/8/141>
- Angelopoulou, A., Economou, D., Bouki, V., Psarrou, A., Jin, L., Pritchard, C., & Kolyda, F. (2012). Mobile augmented reality for cultural heritage. *Mobile Wireless Middleware, Operating Systems, and Applications*, *93*, 15–22. https://doi.org/10.1007/978-3-642-30607-5_2
- Baran, E., Canbazoglu Bilici, S., & Mesutoğlu, C. (2015). Fen, teknoloji, mühendislik ve matematik (FeTeMM) spotu geliştirme etkinliği. *Araştırma Temelli Etkinlik Dergisi*, *5*(2), 60–69.
- Bati, K. (2022). A systematic literature review regarding computational thinking and programming in early childhood education. *Education and Information Technologies*, *27*, 2059–2082. <https://doi.org/10.1007/s10639-021-10700-2>
- Becker, K., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM Education*, *12*(5 & 6), 23–37. <https://www.jstem.org/jstem/index.php/JSTEM/article/view/1509/1394>
- Bell, T., & Lodi, M. (2019). Authors' response: Keeping the “computation” in “computational thinking” through unplugged activities. *Constructivist foundations, Special Issue Constructionism and Computational Thinking*, *14*(3), 357–359.

- Bell, T., & Vahrenhold, J. (2018). CS unplugged—How is it used, and does it work? In H. J. Böckenhauer, D. Komm, & W. Unger (Eds.), *Adventures between lower bounds and higher altitudes* (Lecture notes in computer science) (Vol. 1101). Springer. https://doi.org/10.1007/978-3-319-98355-4_29
- Bell, T., Rosamond, F., & Casey, N. (2012). Computer science unplugged and related projects in math and computer science popularisation. *The Multivariate Algorithmic Revolution and Beyond*, 7370, 398–456. https://doi.org/10.1007/978-3-642-30891-8_18
- Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, 32(3), 347–364. <http://www.jstor.org/stable/3448076>
- Bubikova-Moan, J., Næss Hjetland, H., & Wollscheid, S. (2019). ECE teachers' views on play-based learning: A systematic review. *European Early Childhood Education Research Journal*, 27(6), 776–800. <https://doi.org/10.1080/1350293X.2019.1678717>
- Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using augmented reality in education from 2011 to 2016. *Innovations in Smart Learning*, 13–18. https://doi.org/10.1007/978-981-10-2419-1_2
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.
- Creswell, J. W., & Plano Clark, V. (2018). *Designing and conducting mixed methods research*. Sage.
- Crompton, H., & Burke, D. (2020). Mobile learning and pedagogical opportunities: A configurative systematic review of PreK-12 research using the SAMR framework. *Computers & Education*, 156(June), 103945–103945. <https://doi.org/10.1016/j.compedu.2020.103945>
- Curzan, P., McOwan, P., Plant, N., & Meagher, L. (2014). Introducing teachers to computational thinking using unplugged storytelling. In: *WiPSCe '14* (pp. 89–92). Association for Computing Machinery. isbn: 9781450332507. <https://doi.org/10.1145/2670757.2670767>.
- Doyle, S., & Loveridge, J. (2023). Qualitative research: An introduction. In F. Meyer & K. Meissel (Eds.), *Research methods for education and the social disciplines in Aotearoa New Zealand* (pp. 63–82). NZCER Press.
- Dweck, C. (2007). *Mindset: The new psychology of success, how we can learn to fulfil our potential*. Ballantyne Books.
- Falkner, K., Sentance, S., Vivian, R., Barksdale, S., Busuttil, L., Cole, E., Liebe, C., Maiorana, F., McGill, M. M., & Quille, K. (2019). *An international comparison of K-12 computer science education intended and enacted curricula*. In Proceedings of the 19th Koli calling international conference on computing education research. <https://doi.org/10.1145/3364510.3364517>.
- Feilzer, M. Y. (2010). Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. *Journal of Mixed Methods Research*, 4, 6–16. <https://doi.org/10.1177/1558689809349691>
- Fisher, K., Hirsh-Pasek, K., Golinkoff, R. M., Singer, D. G., & Berk, L. (2012). Playing around in school: Implications for learning and educational policy. In *The Oxford handbook of the development of play* (pp. 342–360). <https://doi.org/10.1093/oxfordhb/9780195393002.013.0025>
- Frey, D., Fisher, N., & Hattie, J. (2016). *Visible learning for literacy: Implementing the practices that work best to accelerate student learning*. Corwin Literacy.
- Frost, N. A., & Shaw, R. L. (2015). Evolving mixed and multimethod approaches in psychology. In S. N. Hesse-Biber & R. B. Johnson (Eds.), *The handbook of multidimensional and mixed methods research inquiry* (pp. 375–392). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199933624.013.24>
- Fullen, M., & Langworthy, M. (2014). *A rich seam: How new pedagogies find deep learning*. Pearson. <https://michaelfullen.ca/a-rich-seam-how-new-pedagogies-find-deep-learning/>. 23 June 2023.
- Golinkoff, R. M., & Hirsh-Pasek, K. (2016). Becoming brilliant: What science tells us about raising successful children. *American Psychological Association*. <https://doi.org/10.1037/14917-000>
- Hall, J. N. (2013). Pragmatism, evidence, and mixed methods evaluation. *New Directions for Evaluation*, 138, 15–26. <https://doi.org/10.1002/ev.20054>
- Hermans, F., & Aivaloglou, E. (2017). *To scratch or not to scratch?: A controlled experiment comparing plugged first and unplugged first programming lessons*. In Proceedings of the 12th

- workshop on primary and secondary computing education, (pp. 49–56). ACM. <https://doi.org/10.1145/3137065.3137072>.
- Huang, W., & Looi, C.-K. (2021). A critical review of literature on “unplugged” pedagogies in K-12 computer science and computational thinking education. *Computer Science Education*, 31(1), 83–111. <https://doi.org/10.1080/08993408.2020.1789411>
- Jackson, C., & Mohr-Schroeder, M. (2018). Increasing stem literacy via an informal learning environment. *Journal of STEM Teacher Education*, 53(1), 4. <https://doi.org/10.30707/JSTE53.1Jackson>
- Jervis, L. M., & Jervis, L. (2005). What is the constructivism in constructive alignment? *Bioscience Education*, 6(1), 1–14. <https://doi.org/10.3108/beej.2005.06000006>
- Kaleci, D., & Korkmaz, Ö. (2018). STEM education research: Content analysis. *Universal Journal of Educational Research*, 6(11), 2404–2412. <https://doi.org/10.13189/ujer.2018.061102>
- Kandlbinder, P. (2014). Constructive alignment in university teaching. *HERDSA News*, 36(3), 5–6.
- Luttrell, W. (2010). ‘A camera is a big responsibility’: A lens for analysing children’s visual voices. *Visual Studies*, 25(3), 224–237. <https://doi.org/10.1080/1472586X.2010.523274>
- Lynch, M. (2015). More play, please: The perspective of kindergarten teachers on play in the classroom. *American Journal of Play*, 7(3), 347–370.
- Markandan, N., Osman, K., & Halim, L. (2022). Integrating computational thinking and empowering metacognitive awareness in stem education. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2022.872593>
- McCruden, M., Marchand, G., & Schultz, P. (2019). Mixed methods in educational psychology inquiry. *Contemporary Educational Psychology*, 57, 1–8.
- Meissel, K., & Brown, G. T. L. (2023). Quantitative research methods. In F. Meyer & K. Meissel (Eds.), *Research methods for education and the social disciplines in Aotearoa New Zealand* (pp. 83–97). NZCER Press.
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2020). *Qualitative data analysis: A methods sourcebook* (4th ed.). Sage.
- Ministry of Education. (2007). *The New Zealand curriculum for English-medium teaching and learning in years 1–13*. Wellington, Learning Media.
- Morris, M. W., Leung, K., Ames, D., & Lickel, B. (1999). Views from inside and outside: Integrating emic and etic insights about culture and justice judgement. *The Academy of Management Review*, 24(4), 781–796. <https://doi.org/10.2307/259354>
- Munasinghe, B., Bell, T., & Robins, A. (2023). Unplugged activities as a catalyst when teaching introductory programming. *Journal of Pedagogical Research*, 7(2), 56–71. <https://doi.org/10.33902/JPR.202318546>
- Passey, D. (2017). Computer science (CS) in the compulsory education curriculum implications for future research. *Education and Information Technologies*, 22, 421–443. <https://doi.org/10.1007/s10639-016-9475-z>
- Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014). *Collaborative augmented reality in education: A review*. In International conference on teaching and learning in computing and engineering (pp. 78–83). <https://doi.org/10.1109/LaTiCE.2014.23>.
- Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, 50(4), 258–283. <https://www.tandfonline.com/doi/abs/10.1080/00461520.2015.1122533>
- Puentedura, R. (2006). *Transformation, technology and education*. <http://hippasus.com/resources/tte/>. 26 June 2023.
- Resnyansky, D., Ibili, E., & Billingham, M. (2018). *The potential of augmented reality for computer science education*. In 2018 IEEE international conference on teaching, assessment, and learning for engineering (pp. 350–356). <https://doi.org/10.1109/TALE.2018.8615331>.
- Romrell, D., Kidder, L., & Wood, E. (2014). The SAMR model as a framework for evaluating mLearning. *Online Learning Journal*, 18(2), 1–15.
- Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review*, 32(1), 77–112.

- Sentance, S., & Csizmadia, A. (2017). Computing in the curriculum: Challenges and strategies from a teacher's perspective. *Education and Information Technologies*, 22, 469–495. <https://doi.org/10.1007/s10639-016-9482-0>
- Taylor, M. E., & Boyer, W. (2020). Play-based learning: Evidence-based research to improve children's learning experiences in the kindergarten classroom. *Early Childhood Education Journal*, 48(2), 127–133. <https://doi.org/10.1007/s10643-019-00989-7>
- Vygotsky, L. S. (1979). The development of higher forms of attention in childhood. *Soviet Psychology*, 18, 67–115. <https://doi.org/10.2753/rpo1061-405180167>
- Webb, M., Davis, N., Bell, T., Yaacov, K. J., Reynolds, N., Chambers, D. P., & Sysło, M. M. (2017). Computer science in K-12 school curricula of the 21st century: Why, what and when? *Education and Information Technologies*, 22, 445–468. <https://doi.org/10.1007/s10639-016-9493-x>
- Winthrop, R., & McGivney, E. (2016). *Skills for a changing world: Advancing skills for a vibrant society*. The Brookings Institution. https://www.brookings.edu/wp-content/uploads/2016/05/Brookings_Skills-for-a-Changing-World_Advancing-Quality-Learning-for-Vibrant-Societies-3.pdf
- Wu, H.-K., Wen-Yu Lee, S., Chang, H.-Y., & Liang, J.-C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62, 41–49. <https://doi.org/10.1016/j.compedu.2012.10.024>
- Zosh, J., Hirsh-Pasek, K., Hopkins, E., Jensen, H., Liu, C., Neale, D., Lynne Solis, S., and Whitebread, D. (2018). Accessing the inaccessible: Redefining play as a spectrum. *Frontiers in Psychology*, 9. <https://doi.org/10.3389/fpsyg.2018.01124>

Chapter 8

Opinion of Spanish Teachers About Artificial Intelligence and Its Use in Education



Juan-Francisco Álvarez-Herrero 

Introduction

Artificial intelligence (AI) is a branch of computer science that tries to understand and simulate the intelligence and behaviour of humans (Wang, 2019). In recent months, there has been a considerable appearance of applications and tools that try, in addition to pursuing the objectives of AI, to make life easier and more effective for people. Among other functions, the AI makes it possible for specific tasks not to be carried out by humans or for tasks in which people could spend much time; thanks to the AI, they are carried out in a few seconds (Mitchell, 2019).

Suppose you have had virtual assistants (Alexa, Siri, etc.) and chatbots that answer frequently asked questions in multiple administrations, organizations or companies for years. In that case, generative AI applications have gained special prominence recently. Notably, one of the best known by society in general is OpenAI ChatGPT. ChatGPT is a chatbot or AI program designed to be able to interact with people in a close language and be able to answer the questions that are asked. Other applications that have become quite famous allow you to generate original images from a simple description (prompt). Among the latter, we find applications such as Dall-E, DreamStudio or Lexica IA.

With these premises, it is unsurprising that AI is also incorporated into the educational field (Chen et al., 2020). Moreover, there are already many experiences in which the use of AI by teachers and students allows for improving the teaching-learning processes.

Among the many advantages that we can find that AI offers in the educational field, we can mention:

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- Access to a multitude of resources and learning materials. From those based on content to complete pedagogical proposals to be taken to the classroom. In addition, these resources will be able to be personalized and contextualized to each specific case, attending to the interests and needs of both the teacher and the students, the main protagonists of the teaching-learning processes. AI applications can be used that are capable of generating a didactic unit, a learning situation or simple learning activities adapted to the situation and the context that is requested. Likewise, the AI can also suggest books, articles, videos and other content necessary for student learning.
- Linking to what was said in the previous section, AI enables and guarantees the personalization of learning. AI through different assessment tools, for example, is capable of meeting the individual needs of students (Zawacki-Richter et al., 2019). Some tools can offer immediate feedback to students, including personalized recommendations for activities that follow the normal development of each student's learning. Moreover, all this always favours equity, treating students fairly without favouring one student over another (du Boulay, 2022).
- Support and feedback in the evaluation and monitoring of students. The AI offers the teacher tools that allow each student to manage, analyse and give feedback immediately (Ali & Abdel-Haq, 2021; Zawacki-Richter et al., 2019). Some tools allow you to analyse the answers and thus give immediate feedback in all types of questionnaires, tests or exams, with which the student can be immediately aware of the mistakes made and thus correct them quickly.
- Virtual and intelligent assistants and tutors. AI-based virtual assistants, as well as chatbots, can offer additional reinforcement when students are outside the classroom, in which they get answers to frequently asked questions and obtain additional or complementary information on specific topics that are being discussed in class, as well as other educational resources that can benefit the student in their learning (Ocaña et al., 2019; Zawacki-Richter et al., 2019).
- Data analysis and decision-making. By analysing large amounts of data, AI, with its tools, can extract helpful information to support all informed decisions by teachers (Ali & Abdel-Haq, 2021). Thus, educational analytics tools that use AI make it possible to identify patterns of student performance and thereby detect areas that require improvement as well as help teachers design more effective learning strategies (Zawacki-Richter et al., 2019).

Thus, some examples of successful good practices in which AI has been implemented in education are:

- Physical education teaching is achieved in an individualized, precise and intelligent way. This has been achieved by incorporating an AI educational robot based on voice interaction into classes, which allows building a hybrid mode of teaching physical education to provide personalized education to students (Yang et al., 2020).
- Chatbots improve student learning outcomes, and it does so more in education students than in primary and secondary education. Likewise, it is verified that

short interventions have a more significant effect on student learning results than long interventions (Wu & Yu, 2023).

- Whether or not to use an integrated approach of AI models and learning analytics (LA) feedback in an online engineering course to examine differences in the collaborative learning effect of students shows that the integrated approach increased student engagement. Students improved collaborative learning performance and strengthened student satisfaction with learning. Hence, AI is again beneficial for student learning (Ouyang et al., 2023).

However, many voices warn of the dangers and fears that the use of AI in the educational field entails. Among the main fears that teachers contemplate when using AI in education are:

- Fear of being replaced. AI is seen as a threat that can replace the role of the teacher in the classroom. It is thought that digital technology can perform teaching tasks more effectively than a teacher can do (Lin et al., 2022).
- Growth of the digital divide and inequality between different groups. AI can increase the existing digital gap between students with greater technology access and those without. In this way, students who do not have access to technology and AI will be included in learning compared to students who do have access to AI and technology (McGrath et al., 2023).
- Universal teaching is far removed from the personalization of learning. It is believed that AI will generate universal, standard teaching that does not meet the personal needs of each student and only generally meets global needs. Likewise, this non-personalized teaching leads to a lack of emotional support a teacher can offer students (Shin, 2020).
- There are fears of a lack of control of the data and that the privacy and security of the same are not ensured. AI collects and analyses a multitude of data in order to be functional. This fosters mistrust among teachers, who fear that these data could be compromised, exposed and accessible to anyone. Moreover, this data should be used more effectively by being able to fall into the hands of people without ethics and control (Bewersdorff et al., 2023).
- Excessive dependence on technology. Abusive use of AI leads to a dependency on it, negatively impacting the students' skills and abilities. Making it easier and faster for them to have a problem solved by the AI instead of them will reduce their ability to solve problems on their own, and with it, they will have less and less intelligence and capacity. The same could be said of other skills, such as critical thinking, interpersonal communication, reasoning, mental calculation, etc. (Antonenko & Abramowitz, 2023).

However, there are three crucial considerations to be made:

- AI is not going to replace the teacher, but rather, it is going to complement it; it is going to make it possible to make them better teachers because they will be able to develop their skills both at the level of professional development and in their work towards the teaching-learning processes (Pedró et al., 2019).

- AI will continue to be with us, and we must take advantage of its educational benefits. It is only necessary to regulate it and train teachers in its use so that they make responsible and effective use, taking into account the ethical and moral considerations that are involved in the teaching-learning processes with the use of AI (Baído-Ánu & Owusu-Ansah, 2023).
- The dizzying pace of the development of new AI applications and tools every minute requires teachers to always be willing to train and renew themselves, always learning to influence the improvement of their students' learning (Chounta et al., 2022).

Hence, this research aims to find out the opinion of Spanish teachers about using artificial intelligence in education. It also seeks to answer questions such as:

- What knowledge do Spanish teachers have about AI?
- What applications do you know?
- What training needs would they have in the hypothetical case of implementing AI in the classroom?

To carry out this research, the following steps were construct a brief questionnaire that was passed to those teachers present on social networks who wanted to participate. The results obtained were analysed and compared with those obtained in other similar investigations in Spain and other countries, and with all this, some conclusions were reached that can be read at the end of this document.

Methodology

This research is exploratory, not experimental, and it tries to collect teachers' opinions from all over Spain through a simple ad hoc questionnaire about their perception of AI and its implementation in education.

The instrument for data collection that has been used responds to a simple self-made questionnaire. The EDUvsIA questionnaire was submitted for judgement and validation by ten education experts working on and researching AI. The ten experts are teachers, and they are from all educational stages considered in the research. The first version passed to the experts underwent some changes and modifications due to the recommendations and comments made by the experts.

The questionnaire is divided into two parts. The first one is with questions of a sociodemographic nature (sex, age, Spanish region, educational stage in which the teaching profession is exercised, seniority or years of teaching experience, ownership of the centre in which they work, and the speciality or nature of the subjects taught). The second part only contains six quick selection questions. Three of these questions are assessed using a Likert scale from 1 to 5, where one is very little or not at all and 5 is a lot or everything.

1. To what extent could you say you feel familiar with AI? 1 (very little or not at all) to 5 (a lot or expert).
2. What AI applications do you know?
 - None.
 - ChatGPT and little else.
 - Some Generative AI: ChatGPT, Dall-E, Midjourney, and some more.
 - All kinds of AI applications, including personalization and machine learning or even programming.
3. Does AI have applications in the educational field that allow it to be implemented by improving the teaching-learning processes of (and with) students? 1 (very few or none) to 5 (many or infinite).
4. Do you consider that AI has an application in the educational field that allows teachers to improve professionally and competently? 1 (very little or not at all) to 5 (a lot or infinite).
5. What would be your position regarding using AI in the educational field with your students?
 - Its use in education should be prohibited.
 - It should be regulated/controlled, leaving some options and prohibiting others.
 - It should be used but always under the supervision and guidance of the teacher (who, in turn, has previously been trained in AI).
 - It should be possible to use it without limits, which implies changes and adaptations in the ways of teaching and learning.
 - Other:
6. If hypothetically, it was decided to implement AI in the educational field in the not-too-distant future, do you feel that:
 - I would be ready for it.
 - I would need to train.
 - I would train myself to know how to use it on a personal level and to detect its use among my students, but I would not use it with it in class.
 - I would train in AI, but I would not use it.
 - I would refuse to train and use it.

This questionnaire was publicized through social networks such as Twitter (now known as X), Facebook, Instagram, Telegram and instant messaging such as WhatsApp. It was always done through channels related to the teaching function and AI. In the different networks that allow it, this questionnaire was disseminated using the relevant educational hashtags to give it greater visibility.

The questionnaire was open for 1 week, between May 23 and May 30, 2023.

Results

A total of 599 valid responses were collected from Spanish teachers from different educational stages. The sample obtained is gender: 314 women (52.4%), 284 men (47.4%), and 1 non-binary (0.2%). Regarding the age of the teachers grouped into different age groups, we can see the results obtained in Table 8.1.

These results regarding the age of the teachers are in line with the reality of the teaching staff in Spain since it is a widely aged group, which in a few years would need a massive generational replacement.

Regarding the educational stages in which teachers work, it is found that responses are given mainly from the stages of secondary (254, 42.4%), primary education (144, 24%), professional training (68, 11.3%), education university (63, 10.5%) and early childhood education (37, 6.2%). The rest corresponds to artistic education, official language schools and adult and non-regulated education.

The teaching experience occurs mainly in those teachers with an experience of between 11 and 20 years (199, 33.2%), between 21 and 30 years (172, 28.7%) more than 31 years (98, 5.2%), while less than 5 years had 72 responses and between 5 and 10 years, 58 responses. Regarding the type of centre, 438 belong to public centres, 114 to subsidized centres and 47 to private centres. For the statistical analysis of the results, the statistical software IBM SPSS Statistics v. 26.0 was used. The quantitative assessment results are shown in Table 8.2.

In the results of Table 8.2, it is verified that the knowledge of Spanish teachers about AI does not reach an average knowledge, standing at a value of 2.51. They do see great possibilities for the use of AI in education, and these are greater in the case that it is used in the professional development of teachers (3.69), compared to using it to improve teaching-learning processes. (3.53). The values of the standard deviations of the three questions confirm a significant disparity between the answers given, finding answers that go from the minimum value (1) to the maximum (5).

Regarding Fig. 8.1, the knowledge teachers have about AI applications and tools, we can see in the following graph how the knowledge is very diverse, with the majority of those teachers having basic knowledge (51.7%), followed by those teachers who know some applications besides ChatGPT.

There is much more consensus on the use of AI in the educational field since 387 teachers (64.6%) would agree to use it in education but always under the supervision and guidance of the teacher (who, at his time, has been previously trained in AI) as can be seen in Fig. 8.2. It should also be noted that only 19 of the 599 teachers would prohibit its use.

Table 8.1 Age of participating teachers

Age	n	%
< 25 years	2	0.3
25–35	69	11.5
36–46	195	32.6
47–57	243	40.6
> 57 years	90	15.0

Table 8.2 Knowledge and possibilities of AI in education

	m	Typical deviation	variance
1.- Knowledge of AI	2.51	1.092	1.194
3.- AI improves the teaching-learning process	3.53	1.169	1.366
4.- AI improves teacher professional development	3.69	1.110	1.232



Fig. 8.1 Knowledge of AI applications by teachers

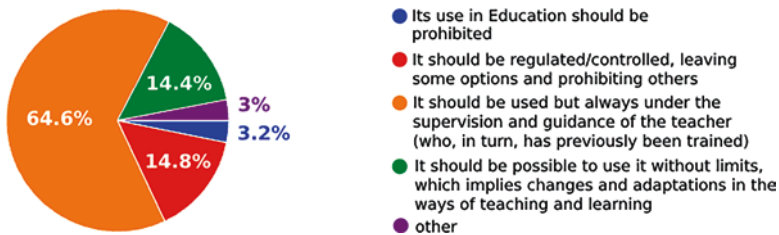


Fig. 8.2 Use that can be given to AI in education

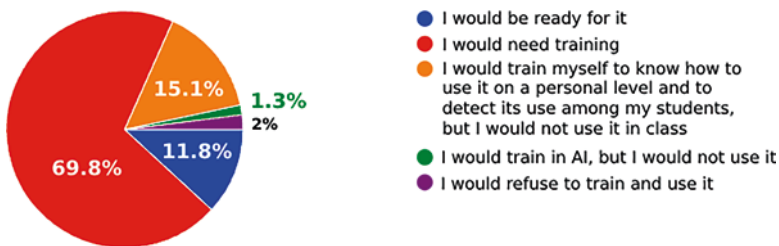


Fig. 8.3 AI training needs in the hypothetical case that had to be implemented in the classroom

Moreover, finally, regarding the need or not training in AI, a large majority of almost 70% (418 teachers) recognize that they would need to be trained to know how to do it in the hypothetical case that AI was implemented in the classroom. Also noteworthy is that only 12 teachers acknowledged that they would refuse to train in AI, and another 8 would train but would not implement it in the classroom, as seen in Fig. 8.3.

Discussion

We have seen how Spanish teachers admit they need to gain notorious knowledge of AI or AI applications and tools that can be used in education. This leads them to recognize a need to train in AI in the hypothetical case that it is implemented in education. However, although they see possibilities of being used in education, their expectations of using AI to improve their professional development are higher than implementing AI in the classroom to improve the teaching-learning processes of their students.

In other similar investigations, teachers from Morocco, Turkey and Sweden also express their fears towards AI but recognize that its application in technical assistance for teaching tasks can be very positive (Douali et al., 2022; Gocen & Aydemir, 2020; McGrath et al., 2023). Specifically, the study by McGrath et al. (2023) identifies fears and scepticism on the part of teachers towards AI in its use in higher education, mainly transferring their concerns to equity and responsibility and the lack of knowledge about AI and its resources.

In Estonia, even though teachers acknowledge having limited knowledge of AI and how it could help them in their teaching work, they confirm that they see AI as an opportunity in the educational world since it would allow them to be more efficient and effective in their work practice, given that AI would offer them that support (Chounta et al., 2022).

Something similar occurs with future Turkish teachers, who see AI in education as bringing benefits and risks (Haseski, 2019).

Like Humble and Mozelius (2019), we are in favour of the fact that sooner rather than later, a debate should be opened on the use and role of AI in education so as not to fall into the error of an artificial education instead of an AI in education. Even as Zawacki-Richter et al. (2019), ethical and educational approaches to the implementation of AI in education should be explored since a lack of critical reflection on the challenges and risks that it entails is detected, as well as a weak connection with pedagogical, theoretical perspectives.

Conclusions

Most Spanish teachers feel they need to become more familiar with AI. Moreover, only a tiny percentage of teachers know of an AI application and tool that goes beyond the most popular, such as ChatGPT. This leads them to request AI training to implement AI in the classroom but always under their supervision and guidance. However, they acknowledge that they feel more confident using AI to improve their professional development as teachers than using it in the classroom to improve teaching-learning processes. These results are very much in line with those obtained in other countries, where it is also observed that, although they are afraid of AI, they feel that it can bring them benefits.

There is still a distrust of the educational use that can be made of AI in the classroom, and to address these fears and promote more excellent knowledge and security, quality training is required in the use and conscientious implementation of AI in the classroom. This implementation must have a reflection from the ethical and educational point of view to make efficient and effective use of it and avoid falling into errors previously committed with other resources and digital devices when incorporating them into the educational world has been considered.

This critical reflection is also necessary to deal with all the fears and inconveniences that teachers consider more frequently with the use of AI in education and thus prevent the real ones and deny the fictitious ones. There is still a long way to go. However, we cannot continue doubting since AI is evolving at a dizzying pace, which means that applications and resources that are much better than those available yesterday have emerged from today to tomorrow.

Although one of the limitations of this research is in the selection of the sample, where only teachers present in social networks have been able to learn about it and participate, it does represent a general feeling of the teachers since these teachers are the ones who they habitually make use of digital technologies in their centres and institutions. Those teachers who are not very interested in AI and its applications in education did not participate either. However precisely, these limitations are the starting point for future research to avoid making the same mistakes.

As future lines of research, we plan to obtain a larger sample in which those teachers who are not so connected to digital technologies are also represented in order to verify if the results remain the same or vary concerning those presented here. Likewise, the aim is to promote and carry out training for active teachers on implementing and using AI in classrooms, both to improve teachers' professional development and their students' learning.

References

- Ali, M., & Abdel-Haq, M. K. (2021). Bibliographical analysis of artificial intelligence learning in higher education: Is the role of the human educator and educated a thing of the past? In M. Ali & T. Wood-Harper (Eds.), *Fostering communication and learning with underutilized technologies in higher education* (pp. 36–52). IGI Global. <https://doi.org/10.4018/978-1-7998-4846-2.ch003>
- Antonenko, P., & Abramowitz, B. (2023). In-service teachers' (mis)conceptions of artificial intelligence in K-12 science education. *Journal of Research on Technology in Education*, 55(1), 64–78. <https://doi.org/10.1080/15391523.2022.2119450>
- Baidoo-Anu, D., & Owusu-Ansah, L. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of AI*, 7(1), 52–62. <https://dergipark.org.tr/en/pub/jai/issue/77844/1337500>
- Bewersdorff, A., Zhai, X., Roberts, J., & Nerdel, C. (2023). Myths, mis- and preconceptions of artificial intelligence: A review of the literature. *Computers and Education: Artificial Intelligence*, 4, 100143. <https://doi.org/10.1016/j.caeai.2023.100143>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, 8, 75264–75278. <https://doi.org/10.1109/ACCESS.2020.2988510>

- Chounta, I. A., Bardone, E., Raudsep, A., & Pedaste, M. (2022). Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education. *International Journal of Artificial Intelligence in Education*, 32(3), 725–755. <https://doi.org/10.1007/s40593-021-00243-5>
- Douali, L., Selmaoui, S., & Bouab, W. (2022). Artificial intelligence in education: Fears and faiths. *International Journal of Information and Education Technology*, 12(7), 650–657. <https://doi.org/10.18178/ijiet.2022.12.7.1666>
- du Boulay, B. (2022). Artificial intelligence in education and ethics. In *Handbook of open, distance and digital education* (pp. 1–16). Springer.
- Gocen, A., & Aydemir, F. (2020). Artificial intelligence in education and schools. *Research on Education and Media*, 12(1), 13–21. <https://doi.org/10.2478/rem-2020-0003>
- Haseski, H. I. (2019). What do Turkish pre-service teachers think about artificial intelligence? *International Journal of Computer Science Education in Schools*, 3(2), 3–23. <https://doi.org/10.21585/ijcses.v3i2.55>
- Humble, N., & Mozelius, P. (2019, October). *Artificial intelligence in education – A promise, a threat or a hype*. In Proceedings of the european conference on the impact of artificial intelligence and robotics (pp. 149–156). Academic Conferences and Publishing.
- Lin, X. F., Chen, L., Chan, K. K., Peng, S., Chen, X., Xie, S., Liu, J., & Hu, Q. (2022). Teachers' perceptions of teaching sustainable artificial intelligence: A design frame perspective. *Sustainability*, 14(13), 7811. <https://doi.org/10.3390/su14137811>
- McGrath, C., Pargman, T. C., Juth, N., & Palmgren, P. J. (2023). University teachers' perceptions of responsibility and artificial intelligence in higher education—an experimental philosophical study. *Computers and Education: Artificial Intelligence*, 4, 100139. <https://doi.org/10.1016/j.caeai.2023.100139>
- Mitchell, M. (2019). *Artificial intelligence: A guide for thinking humans*. Penguin.
- Ocaña-Fernández, Y., Valenzuela-Fernández, L. A., & Garro-Aburto, L. L. (2019). Inteligencia artificial y sus implicaciones en la educación superior. *Propósitos y Representaciones*, 7(2), 536–568. <https://doi.org/10.20511/pyr2019.v7n2.274>
- Ouyang, F., Wu, M., Zheng, L., Zhang, L., & Jiao, P. (2023). Integration of artificial intelligence performance prediction and learning analytics to improve student learning in online engineering course. *International Journal of Educational Technology in Higher Education*, 20(1), 1–23. <https://doi.org/10.1186/s41239-022-00372-4>
- Pedró, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*. UNESCO.
- Shin, D. (2020). An analysis of prospective mathematics teachers' perception of the use of artificial intelligence (AI) in mathematics education. *Communications of Mathematical Education*, 34(3), 215–234. <https://doi.org/10.7468/JKSMEE.2020.34.3.215>
- Wang, P. (2019). On defining artificial intelligence. *Journal of Artificial General Intelligence*, 10(2), 1–37. <https://doi.org/10.2478/jagi-2019-0002>
- Wu, R., & Yu, Z. (2023). Do AI chatbots improve students learning outcomes? Evidence from a meta-analysis. *British Journal of Educational Technology*, 1–24. <https://doi.org/10.1111/bjet.13334>
- Yang, D., Oh, E. S., & Wang, Y. (2020). Hybrid physical education teaching and curriculum design based on a voice interactive artificial intelligence educational robot. *Sustainability*, 12(19), 8000. <https://doi.org/10.3390/su12198000>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—Where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 1–27. <https://doi.org/10.1186/s41239-019-0171-0>

Chapter 9

School Leadership 4.0: Are We Ready?



Norma Ghamrawi , Tarek Shal , and Najah A. R. Ghamrawi 

Introduction

Industry 4.0 represents the fourth phase of the industrial revolution, characterized by the integration of intelligent networking between machines and processes facilitated by information and communications technology (Kaliraj & Devi, 2023). This paradigm shift emphasizes using advanced technologies such as artificial intelligence and robotics, which profoundly impact daily life, including education. Consequently, Education 4.0 describes students' required skill sets to thrive and contribute to their personal and societal growth (Napoleon & Ramanujam, 2023). It refers to a context where students are expected to learn whenever and wherever they can, with the support of emerging technologies of Industry 4.0 (Dao et al., 2023).

However, like any other transformative initiative, the role of school leadership is pervasive in successfully implementing such endeavours (Munna, 2023; Rocha et al., 2021). Leadership facilitates any change process (Ghamrawi, 2010, 2011, 2023; Rocha et al., 2021; Tigre et al., 2023). Numerous studies have demonstrated the significance of school leadership as an indispensable factor in promoting innovation and improvement within educational institutions (Ghamrawi et al., 2023; Ghamrawi & Tamim, 2022; Townsend & MacBeath, 2011; Zhu, 2013). Thus, to

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realize Education 4.0, school leaders assume a fundamental role as facilitators and advocates.

However, there needs to be more research focusing specifically on Education 4.0 in K-12 settings, further compounded by a limited exploration of school leaders' knowledge and preparedness to lead in this new era of schooling. Consequently, this study aims to delve into the knowledge base of school leaders regarding Education 4.0, focusing on their comprehension of its significance within educational contexts and the leadership skills they perceive as essential for successfully spearheading reform agendas of this nature. As such, it addresses the gap in the existing literature by investigating the unavailable knowledge and preparedness of school leaders in K-12 settings regarding Education 4.0. The following research questions guided it:

- How do school leaders evaluate their knowledge and understanding of Education 4.0?
- What are the perceptions of school leaders regarding Education 4.0?
- What leadership skills (Leadership 4.0) do school leaders believe are necessary for leading through Education 4.0?

Literature Review

Education 4.0

The literature identifies four distinct industrial revolutions, each leaving a distinct impact on the field of education (Demartini & Benussi, 2017). The first industrial revolution, Industry 1.0, which occurred in the late eighteenth century, introduced mechanization and steam power machines, consequently influencing Education 1.0 (Devezas & Sarygulov, 2017). The second industrial revolution, Industry 2.0, characterized by mass production, assembly lines, and electric power, laid the foundation for Education 2.0 (Teo et al., 2021). Additionally, Education 3.0 was shaped by the third industrial revolution, which involved automation, computers, and electronics (Teo et al., 2021). The fourth industrial revolution, marked by cyber-physical systems, the Internet of Things, and artificial intelligence, inspires Education 4.0 (Lorenzo et al., 2021).

Education 1.0 refers to traditional education characterized by one-way teacher-centred instruction, while Education 2.0 stands for education enhanced by technology, incorporating some interactive and online elements (Ramírez-Montoya et al., 2022). Moreover, Education 3.0 or learner-centric education emphasizes collaboration, digital literacy, and personalized learning (Huk, 2021). Finally, Education 4.0 refers to education that leverages advanced technology adaptive learning and prepares students for the fourth industrial revolution (Ramírez-Montoya et al., 2022).

The fourth industrial revolution is characterized by the interconnectivity of the Internet in all aspects of life, giving rise to four crucial concepts that shape the future of learning: the Internet of Things (IoT), the Internet of Data (IoD), the

Internet of Services (IoS), and the Internet of People (IoP) (Herold, 2016). IoT refers to the interdependence of various technologies, both with each other and the cloud, while IoD combines operational technology and IoT to regulate and monitor industrial systems. IoS encompasses the necessary components to run software applications, and IoP focuses on the digitalization of relationships, bringing together individuals and personal data processing to facilitate interactive communication (Ramírez-Montoya et al., 2022).

The implications of Industry 4.0 on education are encapsulated in Education 4.0, which is anticipated to bring about a significant leap and paradigm shift in how schools operate and learning is facilitated (Brown-Martin, 2018; Dubovicki & Jukic, 2017; O’Flaherty & Beal, 2018). According to Brown-Martin (2018), Education 4.0 has the potential to empower students as innovators prepared to engage with a highly technological global world. It can transform traditional classrooms focused on facts into simulated environments where students are encouraged to innovate. However, like any technology-driven reform, the digital divide threatens educational inequality (Ghamrawi et al., 2017; Sianturi et al., 2022).

In summary, industrial revolutions have had paradigmatic implications for education, shifting it from lecture-based, rote learning, and memorization (Education 1.0) to Internet-enabled learning (Education 2.0), knowledge-based education (Education 3.0), and, ultimately, innovation-based education (Education 4.0). Unfortunately, many studies critique schools for remaining entrenched in Education 1.0 while claiming to offer Education 2.0 and 3.0, emphasizing the need for schools to actively embark on learning journeys inspired by Education 4.0 (Ghamrawi et al., 2017; Çetin & Karsantık, 2022).

Concepts and Terms Associated with Education 4.0

Numerous tools are deemed indispensable for implementing Education 4.0 within educational institutions. These encompass a wide range of technological advancements such as ‘3D printing, augmented reality, virtual reality, cloud computing, holograms, biometrics, multi-touch LCD screens, the Internet of Things, artificial intelligence, big data, QR codes, and more’ (Halili, 2019, p. 63). Table 9.1 showcases a selection of these terms alongside their practical applications in student learning.

Furthermore, Education 4.0 encompasses three innovative pedagogical approaches: heutagogy, peeragogy, and cybergogy (Bizami et al., 2022). Heutagogy is a learner-centred approach that empowers students to take charge of their learning (Blaschke, 2012; Kapasi & Grekova, 2018). It is often called ‘self-directed learning’ or ‘self-determined learning’ (Kapasi & Grekova, 2018). Grounded in students’ reflective practices (Bizami et al., 2022), heutagogy heavily relies on technological tools, necessitating teachers and students to possess digital competencies (Blaschke, 2012).

Table 9.1 Terms associated with Education 4.0

Term	Illustration
3D printing	Students' view is not only limited to textbook pictures; by using this 3D printer, students will have access to 3D models of different elements, which 3D view helps them to have a more profound understanding of their subjects
Augmented reality	Augmented reality helps students gain interest in learning because this technology provides an indirect vision of a real-world setting. Students will experience getting physical with better sensory inputs and graphics elements
Virtual reality	This technology helps students gain deeper engagement compared to a traditional textbook. They will gain visual elements to connect learning concepts and information effectively
Cloud computing	This advanced technology helps students lessen the burden of carrying their homework, heavy textbooks, and assignments. With an internet connection, they can access their work at home from their class anytime and anywhere
Holograms	This technology helps students gain deeper engagement compared to a traditional textbook. They will gain visual elements to connect learning concepts and information effectively
Biometrics	Facial recognition, fingerprints, and eye tracking help ease class attendance, saving time in the classroom for security purposes and creating a better understanding of student engagement. This technology can be used in libraries to identify students borrowing books
Paper-thin smartphone	This technology is durable or unbreakable, offers interactivity in the classroom, and is paperless. A paper-thin smartphone operates like a small sheet of interactive paper. This means that when students are reading, they do not feel like they are holding a sheet of glass or metal
Multi-touch LCD screen	This technology presents the perfect presentation solution to the traditional giant board in front of the classroom. Students will sit around the table tablet, swipe on the board to manipulate and drag images around the screen, or type notes with their onscreen keyboards
Internet of things	The internet of Things influences education, specifically with the ever-growing popularity of mobile devices. This technology helps to establish rapid communication and interaction between the students and teachers in and outside the classroom
Artificial intelligence	This technology can accelerate the teaching and learning process and improve the student learning experience. It can reduce the irrelevant work teachers have to do now and then so they can focus more on meaningful learning experiences for the students
Big data	This technology helps the institution manage data in which it is possible to find evidence and facilitate data interchange among institutions and students. For instance, the institutions can identify how well students are learning, students' dropout patterns, and academic performance or predict any information related to attendance patterns
QR code	A quick response (QR) code is a digital image available from free QR scanner apps that can be scanned using any device such as mobile, iPad, laptop, etc. when the students scan the code, it will be taken directly to a website. This technology used in the classroom can reduce the frustration of long web addresses, be user-friendly, and save time when they can quickly scan the QR code easily to the website

In addition, ‘peeragogy’ or ‘paragogy’ is a collaborative peer learning approach where peers engage in co-learning and co-creation of knowledge (Mulholland, 2019). This approach is founded on sharing power among peers, encompassing interactivity, collaboration, responsibility, meanings, and knowledge sharing (Bizami et al., 2022). Above all, students must be empowered in the pedagogy learning approach and possess digital literacy skills, as this approach heavily relies on technology in blended learning contexts.

Moreover, ‘cybergogy’ involves engaging students in online virtual learning environments, fostering cognitive, emotional, and social learning (Stukalo, 2021). This approach often takes the form of virtual learning communities (Miranda et al., 2021), which promote active engagement in discussions, collective problem-solving, and collaborative exchange of ideas (Ghamrawi, 2022). Implementing this approach successfully requires advanced technological competencies and digital literacy for students and teachers (Bizami et al., 2022).

The Leadership Challenge

Leadership is the cornerstone of any effective educational reform initiative (Bush, 2020; Harris & Johnston, 2010; Ghamrawi & Tamim, 2022). School leaders are portrayed as catalysts of change who mobilize the entire school community towards meaningful reforms (Acton, 2021). Education 4.0 is no exception and demands school leaders to act as change agents who support a reform rooted in new technologies. Education 4.0 necessitates school leaders to demonstrate digital leadership skills (Ghamrawi & Tamim, 2022). This is because the literature suggests that introducing technology in educational settings is often driven by individuals in key leadership positions (Ghamrawi & Tamim, 2022; Navarro-Martinez & Peña-Acuña, 2022).

The literature underscores the criticality of comprehensively understanding the change process when implementing reforms. Marzano et al. (2005) caution that ‘if leadership techniques do not align with the required order of innovation change, the innovation will likely fail regardless of its merits’ (p. 66). Similarly, Richard (1996) argues against the naive notion that reforms seamlessly permeate classrooms without intentional leadership efforts. Prestiadi et al. (2020) contend that Education 4.0 may only be attainable if school leaders embrace transformational leadership and effectively execute it within their specific school contexts. They argue that trust is a foundational prerequisite for innovation, as teachers may need more trust to take risks, with the trust often associated with transformational leadership. This aligns with Fullan’s (2016) assertion that leading change is an intricate task, and school leaders often need to be more prepared to undertake it. He suggests that given the rapid pace and profound magnitude of change impacting education, there is a pressing need to equip school leaders with the skills of change agents.

Furthermore, Breakspear et al. (2017) propose that agile leadership is indispensable for reform initiatives that are exceedingly complex, unpredictable, and volatile. Agile leadership recognizes the significance of moving beyond a singular focus on

the principal and instead seeks to develop leadership capabilities at all levels of the organization. Agile leaders prioritize people, embrace democratic approaches, and foster inclusivity. They place trust in their teams and empower them with the autonomy to self-organize and deliver at a high level of quality (Breakspear, 2017).

On the other hand, Ghamrawi and Tamim (2022) put forth a '5D typology' for digital leadership, encompassing the following attributes: (1) digital competence, (2) digital culture, (3) digital differentiation, (4) digital governance, and (5) digital advocacy. They explain their typology by stating that:

Digital leadership relies heavily on the expert knowledge of leaders in position. They should be able to use effectively any digital technologies they aim at expanding within their contexts. They should create a positive culture around shared values of student learning. Through this, digital leaders ensure that members can work and collaborate under the same vision, leading to the outcomes that constitute the project's key performance indicators. However, this positive environment must be further pushed towards achieving its goals through a governing body that secures accountability, liability and responsibility. Finally, digital leaders should market their ideas and the digital technologies they are after. Through advocacy, leaders serve as eye openers for community members towards the benefits they would make from espousing the desired digital tools, one of which is the differentiated learning opportunities they secure (p. 16).

In addition, Education 4.0 encompasses not only technical aspects but also ethical and moral considerations. Erdoğan Coşkun (2022) highlights that one of the significant challenges associated with Education 4.0, following digital competency and literacy, is the need to revamp schools' standards in terms of moral and ethical dimensions. Schools are viewed as social entities that both influence and are influenced by society. Therefore, Coşkun emphasizes the importance of balancing the focus on technical skills with a conscientious commitment to maintaining an education system that upholds moral and ethical values.

Building upon this notion, the term 'Leadership 4.0' refers to the skill set required by school leaders to navigate the Education 4.0 reform. In this study, we explore Leadership 4.0 skills from the perspective of school leaders, ensuring they possess adequate information and knowledge regarding Education 4.0. Additionally, their perceptions regarding this new wave of educational reform are examined in-depth.

Methodology

Research Method and Design

A qualitative research approach was employed to investigate school leaders' knowledge and perceptions regarding Education 4.0 and the corresponding leadership skills required for its successful implementation (referred to as Leadership 4.0 in this study). Specifically, four focus group interviews were conducted involving 16 school leaders from 8 different countries. The participants were selected based on their attendance at a webinar on Education 4.0 organized by one of the researchers. Each focus group consisted of four subject leaders and lasted approximately 45 min.

Table 9.2 Focus group interview schedule

Introduction
Welcoming, self-introductions, overview of the topic, informed consent, and ground rules
Knowledge of education 4.0
On a scale of 1–10 (1 being the lowest):
How do you evaluate your prior knowledge of education 4.0 prior to the webinar?
How do you think this score has improved post the webinar?
What elements of education 4.0 were known to you before a presentation?
What elements of education 4.0 surprised you during a presentation?
Perceptions towards education 4.0
How do you think education 4.0 will impact schools?
To what degree will education 4.0 influence learning positively?
What negative influences do you anticipate for education 4.0 on schooling?
Leadership 4.0 skills
To what degree are you ready to lead education 4.0 in your school?
What are the necessary skills that would be most important for your success in leading education 4.0?

As Krueger and Casey (2015) recommended, focus group interviewing was deemed suitable for exploring perspectives on new issues and ideas. This method facilitated the acquisition of deep, empathetic understanding and in-depth comprehension of participants’ perceptions, insights, attitudes, experiences, and beliefs (Okoko, 2023). By bringing together multiple participants, focus groups provided a unique platform for exploring new ideas fostering group thinking within a specific context (Okoko, 2023).

A focus group interview schedule, presented in Table 9.2, was developed to guide the data collection process and address the research questions.

Data Collection and Analysis

Following participants’ consent, focus group interviews were conducted, and the discussions were recorded. The recorded interviews were then transcribed for further analysis. The collected data was analysed using a theme-based approach involving several stages, including open, axial, and selective coding. This process constructed meaning by identifying and exploring the themes from the data (Williams & Moser, 2019).

The Sample

Selective sampling was utilized to identify the participants for the study. Out of the 28 (K-12) school principals who attended the ‘Education 4.0’ webinar organized by one of the researchers, 16 principals were selected to participate based on their

Table 9.3 Characteristics of the sample

Characteristic	Number
Gender	
Male	6
Female	10
Age (years)	
25–35	5
36–45	10
Above 45	1
Education	
BA	11
MA	5
PhD	0
Teaching experience (years)	
3–10	5
More than 10	12
School principal experience (years)	
0–9	0
10–15	7
>16	9

experience leading a school for 10 years or more. Although 18 school principals were eligible to participate, only 16 agreed to participate in the study. Therefore, the final sample consisted of 16 school principals, and their characteristics are detailed in Table 9.3.

Finally, participants' countries included Egypt (2), Jordan (3), Kuwait (1), Lebanon (2), Oman (2), Qatar (2), Saudi Arabia (1), and the United Arab Emirates (3).

For ethical considerations, participants are identified using the formula FG_xP_y -Country. FG stands for 'focus group', and x represents its number. Moreover, 'P' stands for the participant, and y denotes the number given to him/her. Finally, the name of the country of the participant is written next. For example, FG_2P_3 -Egypt denotes an Egyptian participant, given number 3 in the second focus group.

Knowledge of Education 4.0

All participants said they had yet to hear about Education 4.0, and their first encounter with the concept was through the webinar they attended with one of the researchers of this study. That is why their score out of 10 about Education 4.0 before the webinar ranged from 0 to 4, with an average of 2 out of 10 for the whole group. This range was improved to 6–8 post the webinar, with an average of 7 out of 10.

'I have never heard of Education 4.0 before. It is a new concept I am hearing of for the first time only through the webinar' (FG_1P_2 -Jordan).

However, almost half of the participants have heard of some of the terms associated with the concept of Education 4.0. The key terms that were recognizable by this group related to 3D printers, holograms, and QR codes.

‘I have heard of 3D printing, holograms, and QR codes. I have seen holograms in some malls used for advertisements by some shops, and I know what a QR code is. I did not know that these things will soon be part of what we should use for student learning’ (FG3-P4-Oman).

Moreover, they converged on artificial intelligence when asked about the elements of Education 4.0 that mostly surprised them. They thought it would be a groundbreaking approach to individualizing and differentiating learning.

‘I am speechless hearing what artificial intelligence can do in education. I do not think there will be any student who cannot learn with such a level of tailored learning’ (FG2-P3-Lebanon).

Perceptions Towards Education 4.0

All participants in this study bluntly expressed fear of Education 4.0, believing it would bring a radical change in learning and teaching.

‘I sincerely feel afraid and even threatened because what I learned about the tools that might soon be available for student learning is quite big’ (FG4-P1-Kuwait).

Despite expressing fear of Education 4.0, which we argue is regular with vigorous change initiatives, participants also thought that Education 4.0 would augment student learning experience by offering exciting learning opportunities for students, which, in effect, might transform schooling positively.

‘I am afraid of this change, but if the initiative succeeds, it may positively influence schools, probably shifting practices to a new level’ (FG4-P4-UAE).

Moreover, participants suggested that Education 4.0 can secure individualized learning opportunities for students, allowing them to learn based on their needs, interests, and abilities.

‘A value for Education 4.0 would be securing the provision of individual learning for all students. We always speak of the importance of individualized learning, but I do not think we realize it. Probably Education 4.0 can secure it’ (FG3- P3- Jordan).

Education 4.0 was believed to allow teachers to provide students with instant feedback, which would help them identify their weaknesses and figure out how to address them.

‘It is amazing how Education 4.0 would foster immediate feedback to students. It would help all students learn and improve’ (FG2-P2- Qatar).

In the same vein, school leaders thought that Education 4.0 could empower teachers, as it provides tools that reduce administrative burdens, which for long they believed took a significant part of their time. The bottom line is that teachers would have more time to focus on student learning and hence leverage the quality of student learning outcomes.

'I think a bulk of administrative work will be removed off the shoulders of teachers. This would allow them to focus entirely on student learning' (FG1-P1-Egypt).

Likewise, school leaders thought that Education 4.0 could inherently support the running of educational institutions more efficiently by reducing the heavy administrative tasks incurred on school leaders and their teams.

'The same way teachers will get less burdened with administrative tasks, we [school leaders] will be too less burdened with administrative tasks' (FG3-P1-UAE).

On the other hand, participants thought that Education 4.0 would support proper alignments between what students learn at school versus job market skills.

'The key value of this reform initiative is the degree to which it makes learning compatible with future jobs that students would occupy' (FG1-P4-Qatar).

Over and above, participants considered Education 4.0 to possess strong potential for managing crisis education. They contended that pandemics would not constitute any threats anymore when this initiative is successfully implanted.

'I can see a powerful potential for Education 4.0 in combating education disruption due to pandemics. If this learning model were in place when COVID-19 hit us all, learning would have been least impacted' (FG4- P2-Jordan).

However, school leaders thought that Education 4.0 could cancel physical schools, thinking that students might be able to learn anywhere they would be and at any time.

'We might soon say goodbye to schools as we historically knew them. I guess students would learn from a distance as there will be no need for physical buildings' (FG2- P2-Oman).

Moreover, participants thought that Education 4.0 would increase student isolation, decrease their social skills, confine them to machines, and negatively influence their well-being.

'I am afraid that this approach to education will imprison students behind screens. This, in effect, will not allow them to socialize with peers. The result would be problematic for students suffering social withdrawal' (FG2-P1-Oman).

In addition, participants expressed concerns about parents' inability to follow up with their children's learning, as the new approach to education would require advanced digital expertise, which they thought needed to be improved.

'I cannot imagine my students' parents being able to cope with the skills needed for them to catch up with what their children would be learning' (FG3-P1-Egypt).

Finally, participants thought that Education 4.0 would increase the digital divide and contribute to education inequalities and injustice. Education 4.0 requires advanced technology, which might only be available for some students due to their varied socioeconomic statuses.

'My biggest fear is that this approach to learning could support inequalities between students based on whose parents would have enough money to buy technological devices, just as was the case during the COVID-19 pandemic' (FG4-P3-Lebanon).

Leadership 4.0

All participants believed their schools needed more time to prepare for this initiative regarding teachers' and students' readiness. They suggested that the new education reform requires advanced digital skills, which need to be improved for all school community members. They thought schools should become digital learning communities, suggesting the urgent need to enhance teachers' and students' skills, arriving at Teacher 4.0 and Student 4.0.

'The reform is rooted in digitalization. It will not succeed unless teachers' and students' technical and digital skills are leveraged to meet the requirements of Education 4.0. They need to be compatible' (FG1-P4-Qatar).

Likewise, school leaders believed they needed more advanced digital literacy to lead such an initiative. They contended that school leaders were meant to serve as motivators who provided direction and created a work climate conducive to this initiative's success. However, their role would be jeopardized when their knowledge and skills underlying this initiative are modest.

'You cannot lead on something you are not competent in, and this is the major challenge confronting us with this initiative' (FG3-P2-UAE).

Moreover, school leaders suggested that with this initiative, more than ever, they would need to build on a robust foundation of transformational leadership skills. This would help them improve organizational performance by generating stakeholder commitment and increasing satisfaction and trust in all school community members.

'We should be able to serve as trustworthy leaders who inspire school members to innovate and develop new learning methods. We must be trusted to support Education 4.0' (FG1-P3-Saudi Arabia).

Furthermore, school leaders hinted at distributed and teacher leadership without naming them. They suggested that, within the new context of Education 4.0, teachers must be empowered, act more independently, and be self-reliant.

'We need to catch up on how teachers perform their school roles. They are too dependent on subject coordinators. With this initiative, each teacher needs to be a subject coordinator to manage through the challenges and the surprises that this initiative can potentially bring along' (FG2-P4-UAE).

School leaders thought that this initiative would only succeed with professional development designed to leverage their competencies and those of their teachers. Both parties would need to learn how to harness technology for student learning rather than becoming tools for machines of Education 4.0.

'There is a strong need to make everyone understand that robots will not replace teachers and school principals. So, there is an urgent need to design training programs that illustrate pedagogic tools 4.0, if I may call them like this. Technology should be there to serve learning, and not captivate it' (FG3-P4-Oman).

In addition, school leaders thought that the new initiative entailed a mind shift in student assessment and evaluation. They thought there would be a need to enact a new philosophy that stopped equating education with knowledge acquisition.

Contrarily, it should focus on students' abilities in solving real-life problems through design thinking.

'We need to forget all about the true and false exams and step into inviting students to showcase their skills by designing products that solve real-life problems' (FG4-P3-Lebanon).

School leaders emphasized well-being leadership. They thought they would need to be trained on securing the well-being of themselves, teachers, and students within this complex educational context. They thought that all school community members were prone to emotional distress. As leaders, they were supposed to put preventive and curative measures in place for securing well-being.

'I think all of us in schools would confront one or more forms of depression and anxiety, so we [school leaders] would need to be well prepared to put in place a system for securing well-being for all school members, including us. We should be able also to cure cases that might arise' (FG1-P2-Jordan).

Finally, ethical leadership is viewed as prevalent for leading Education 4.0. With this, school leaders should model ethics and moral issues themselves, ensuring it is well cascaded to teachers and students.

'We should work more on demonstrating ethics and moral values to all school members. With simple tools we use at schools, we suffer from cheating and cyberbullying. So with big data and artificial intelligence, we must be very cautious about personal privacies and other ethical considerations' (FG2-P2-Qatar).

Discussion

This study investigated the concept of Leadership 4.0, focusing on the essential skills school leaders require to navigate and lead effectively in the context of Education 4.0. Additionally, it explored their knowledge base and perceptions concerning Education 4.0. The research was conducted after a webinar on Education 4.0 organized by one of the researchers. The findings indicate that school leaders needed more prior knowledge of Education 4.0; they needed to familiarize themselves with the term before the webinar, despite some awareness of related concepts. However, they needed a clearer understanding of how these terms related to education. This finding aligns with standard practice, where policymakers often must include school leaders in planning reform initiatives (Bros & Schechter, 2022), resulting in delayed implementation and limited impact (Payne, 2008).

Furthermore, the study reveals that school leaders, like any significant change, experienced apprehension. They openly expressed concerns that this reform initiative could substantially transform the educational landscape or render it obsolete, thereby threatening traditional schooling. This aligns with existing literature, which suggests that resistance and a fear of losing competence are common reactions to change (DeMatthews et al., 2021). Additionally, school leaders voiced worries about the well-being of their schools, believing that their unpreparedness to lead this change could negatively impact their well-being and that of teachers and

students. This corresponds with literature emphasizing the importance of maintaining well-being within the entire school community during periods of change (Hanley et al., 2020).

Similarly, school leaders expressed concerns about parents' ability to keep pace with Education 4.0, as it requires advanced digital skills, which many parents need more. This aligns with the findings of Ghamrawi et al. (2017), suggesting that parental engagement in their children's education decreases when schools adopt advanced technologies. Similarly, Sianturi et al. (2022) emphasized the need to ensure parental involvement when selecting educational technology.

Moreover, school leaders highlighted the potential for Education 4.0 to exacerbate the digital divide and perpetuate educational inequalities based on students' and families' socio-economic statuses. They believed that families with access to new technologies would give their children an advantage in learning, while others would be left behind. This observation aligns with arguments by Ghamrawi et al. (2017) and Sianturi et al. (2022), suggesting that a heavy reliance on technology in education may lead to undesirable consequences.

However, school leaders also recognized the benefits of Education 4.0 in enhancing learning quality. They believed it could revolutionize differentiated and individualized learning and provide immediate feedback to students. This aligns with existing literature by authors such as Brown-Martin (2018), Dubovicki and Jukic (2017), and O'Flaherty and Beal (2018), who have emphasized the potential of Education 4.0 to enhance learning quality and offer differentiated learning opportunities with prompt feedback. Additionally, they believed that Education 4.0 could better prepare students for the job market, a point emphasized by Brown-Martin (2018).

Furthermore, school leaders saw the empowerment aspect of Education 4.0 for themselves and teachers. They recognized that realizing the potential of Education 4.0 required teacher empowerment through distributed and transformational leadership and the implementation of teacher leadership. They stressed the importance of fostering trusting school relationships between senior leadership and teachers to encourage risk-taking and enable them to embark on this new journey. Teacher leadership has been widely acknowledged in the literature as a supportive element in educational reform (Little, 2003; Nguyen et al., 2022).

Regarding the essential school leadership skills required to realize Education 4.0, participants identified distributed, transformational, digital, well-being, and ethical leadership. They believed that school leaders needed to be digitally literate to effectively manage this reform initiative, as they cannot lead in areas they need to be more familiar with. Digital leadership has gained recognition in the literature, as highlighted by Ghamrawi and Tamim (2022), as integral to the success of any technology reform initiative. School leaders also emphasized the importance of addressing the well-being of the school community, as a demanding reform initiative can pose significant challenges. This aligns with literature such as Netolicky (2020), who emphasizes the importance of navigating tensions and employing techniques to safeguard well-being. Additionally, school leaders believed that ethical and moral leadership was more crucial than ever within this reform initiative due to its

potential ethical risks. This corresponds to the assertions made by Erdogan Coskun (2022), underscoring the centrality of ethical leadership in digitalized workplaces.

The collection of leadership skills identified by the participants closely aligns with the agile leadership concept, as Breakspear (2017) described. According to Breakspear et al. (2017), agile leadership involves operating in conditions of ambiguity and uncertainty, being responsive, quickly identifying emerging problems or opportunities, and working through short iterative cycles of adaptation, learning, and improvement. School leaders are transformational through agile leadership, share power, and prioritize morality and humanity.

Furthermore, school leaders believed that Education 4.0 was well suited for crisis management. However, they also recognized that its success relied on leveraging the capacity of the entire school community through well-planned professional development. According to the literature, technology is believed to support crisis management (Ghamrawi, 2022), and success hinges on tailored professional development programmes (Netolicky, 2020).

Finally, this study's sample size of 16 school principals may be considered relatively small for generalizations. However, we contend that the thorough and transparent procedures increase its trustworthiness. Moreover, in case studies, prominent researchers such as Robert Yin, Sharan Merriam, and Robert Stake suggest that case study methodologies can be used to generate theories (Yazan, 2015). Siggelkow (2007, cited in Yazan, 2015) argues that even a single case study can be powerful enough to challenge widely held views.

Conclusion

Education 4.0 is rapidly approaching the doors of schools, yet many school leaders need to be made aware of its existence. These leaders are pivotal in implementing reform initiatives and reshaping student learning in collaboration with their school communities. However, when school leaders need more knowledge and skills to lead a specific reform, it can impede its successful execution. This study highlights the unfortunate reality that despite policymakers' growing emphasis on school leadership and leadership development worldwide in recent decades, these leaders continue to be marginalized and relegated to mere recipients of reform agendas rather than active contributors. Policy structures and leadership agencies must adopt a different approach to facilitate effective reform, moving from hierarchical and bureaucratic controls towards lateral collaboration and constructive interdependence. This shift suggests the co-construction of reform agendas, which supports building reform agendas with schools rather than constructing such agendas for them.

The study also unveils a potential crisis looming, wherein schools may face significant challenges in implementing the Education 4.0 reform initiative, potentially surpassing the difficulties encountered during the COVID-19 crisis. It is imperative to enhance the awareness and capacity of school leaders regarding this reform by

focusing on developing a diverse range of leadership skills necessary for managing success. School leaders must be equipped to navigate the tensions they are likely to encounter without succumbing to the pressures of performative measures that prioritize external goals at the expense of the well-being of schools. In this regard, the opinions of school leaders regarding the skills they require to achieve success should not be underestimated. Education 4.0 represents a monumental change, and school leaders must uphold this reform by adhering to conventional change management processes that often result in failure or superficial implementation. Instead, school leaders should be empowered to lead this reform within their schools, engaging in critical inquiry, shaping the reform, and fostering a deep understanding of the initiative among all school members.

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Informed Consent All participants in this study were informed of the purpose of the study and how data will be used. They were assured that their identities would remain anonymous across the study.

Ethics Approval This study gained the approval of the IRB net at Qatar University (QU-IRB 1866-EA/23).

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References

- Acton, K. S. (2021). School leaders as change agents: Do principals have the tools they need? *Management in Education*, 35(1), 43–51.
- Bizami, N. A., Tasir, Z., & Kew, S. N. (2022). Innovative pedagogical principles and technological tools capabilities for immersive, blended learning: A systematic literature review. *Education and Information Technologies*, 1–53.
- Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distributed Learning*, 13(1), 56–71. <https://doi.org/10.19173/irrodl.v13i1.1076>
- Breakspear, S. (2017). Embracing agile leadership for learning: How leaders can create impact despite growing complexity. *Australian Educational Leader*, 39(3), 68–71.
- Breakspear, S., Peterson, A., Alfadala, A., & Khair, M. S. B. M. (2017). *Developing Agile leaders of learning: School leadership policy for dynamic times*. World Innovation Summit for Education (WISE) Research Series.
- Bros, E., & Schechter, C. (2022). The coherence challenge between policy makers and school leaders: Exploring a national pedagogical reform. *Journal of School Leadership*, 32(5), 488–513.
- Brown-Martin G. (2018). *Education and the Fourth Industrial Revolution*. <https://medium.com/learning-re-imagined/education-and-the-fourth-industrial-revolution-cd6bcd7256a3>
- Bush, T. (2020). History of educational Administration in the United Kingdom. In *Oxford research encyclopedia of education*. Oxford University Press.
- Çetin, M., & Karsantık, I. (2022). Current trends in school management: School leadership in education 4.0. In *Educational theory in the 21st century: Science, technology, society and education* (pp. 197–216). Springer.

- Chase. https://executiveacademy.at/fileadmin_synced_assets/documents/White_Papers/Leadership-in-Fourth-Industrial-Revolution-Stanton-Chase.pdf
- Dao, L. T., Tran, T., Van Le, H., Nguyen, G. N., & Trinh, T. P. T. (2023). A bibliometric analysis of research on education 4.0 during the 2017–2021 period. *Education and Information Technologies*, 28(3), 2437–2453.
- Demartini, C., & Benussi, L. (2017). Do web 4.0 and industry 4.0 imply education X. 0? *IT Professional*, 19(3), 4–7.
- DeMatthews, D. E., Serafini, A., & Watson, T. N. (2021). Leading inclusive schools: Principal perceptions, practices, and challenges to meaningful change. *Educational Administration Quarterly*, 57(1), 3–48.
- Devezas, T., & Sarygulov, A. (2017). *Industry 4.0*. Springer.
- Dubovicki, S., & Jukic, R. (2017). The importance of acquiring pedagogical and didactic competencies of future teachers – The Croatian context. *Early Child Development and Care*, 187(1), 1557–1567. <https://doi.org/10.1080/03004430.2017.1307839>
- Erdoğan Coşkun, A. (2022). Conceptions of society and education paradigm in the twenty-first century. In *Educational theory in the 21st century: Science, technology, society and education* (pp. 141–171). Springer.
- Fullan, M. (2016). The elusive nature of whole system improvement in education. *Journal of Educational Change*, 17(4), 539–544.
- Ghamrawi, N. (2010). No teacher left behind: Subject leadership that promotes teacher leadership. *Educational Management Administration & Leadership*, 38(3), 304–320.
- Ghamrawi, N. (2011). Trust me: Your school can be better – A message from teachers to principals. *Educational Management Administration & Leadership*, 39(3), 333–348.
- Ghamrawi, N. (2022). Teachers' virtual communities of practice: A strong response in times of crisis or just another Fad? *Education and Information Technologies*, 27(5), 5889–5915.
- Ghamrawi, N. (2023). Toward agenda 2030 in education: Policies and practices for effective school leadership. *Educational Research for Policy and Practice*, 1–23.
- Ghamrawi, N., & Tamim, R. (2022). A typology for digital leadership in higher education: The case of a large-scale mobile technology initiative (using tablets). *Education and Information Technologies*, 1–22.
- Ghamrawi, N., Ghamrawi, N. A., & Shal, T. (2017). Lebanese public schools: 20th or 21st century schools? An investigation into teachers' instructional practices. *Open Journal of Leadership*, 6(1), 1–20.
- Ghamrawi, N., Shal, T., & Ghamrawi, N. A. (2023). The rise and fall of teacher leadership: A post-pandemic phenomenological study. *Leadership and Policy in Schools*, 1–16.
- Halili, S. H. (2019). Technological advancements in education 4.0. *The Online Journal of Distance Education and e-Learning*, 7(1), 63–69.
- Hanley, T., Winter, L. A., & Burrell, K. (2020). Supporting emotional well-being in schools in the context of austerity: An ecologically informed humanistic perspective. *British Journal of Educational Psychology*, 90(1), 1–18.
- Harris, M., & Johnston, M. A. (2010). Values-based leadership: At the heart of sustaining school reform and improvement. *School Leadership-International Perspectives*, 10, 145–158.
- Herold, G. (2016). *Leadership in the fourth industrial revolution*. Stanton.
- Huk, T. (2021). From education 1.0 to education 4.0-challenges for the contemporary school. *The New Educational Review*, 66, 36–46.
- Kaliraj, P., & Devi, T. (2023). Innovating higher education 4.0 in the era of industry 4.0. In *Industry 4.0 technologies for education* (pp. 1–10). Auerbach Publications.
- Kapasi, I., & Grekova, G. (2018). What do students think of self-determined learning in entrepreneurship education? *Education and Training*, 60(7/8), 841–856. <https://doi.org/10.1108/et-02-2017-0028>
- Krueger, R. A., & Casey, M. A. (2015). Focus group interviewing. In *Handbook of practical program evaluation* (pp. 506–534). Wiley.

- Little, J. W. (2003). Constructions of teacher leadership in three periods of policy and reform activism. *School leadership & management*, 23(4), 401–419.
- Lorenzo, N., Gallon, R., Palau, R., & Mogas, J. (2021). New objectives for smart classrooms from industry 4.0. *Technology, Knowledge and Learning*, 26(4), 719–731.
- Marzano, R. J., Waters, T., & McNulty, B. A. (2005). School leadership that works: From research to results. ASCD.
- Miranda, J., Ramírez-Montoya, M. S., & Molina, A. (2021, November 22–24). *Education 4.0 reference framework for the design of teaching-learning systems: Two case studies involving collaborative networks and open innovation*. In Smart and sustainable collaborative networks 4.0: 22nd IFIP WG 5.5 working conference on virtual enterprises, PRO-VE 2021, Saint-Étienne, Proceedings 22 (pp. 692–701). Springer.
- Mulholland, N. (2019). *Re-imagining the art school: Paragogy and artistic learning*. Springer. <https://doi.org/10.1007/978-3-030-20629-1>
- Munna, A. S. (2023). Instructional leadership and role of module leaders. *International Journal of Educational Reform*, 32(1), 38–54.
- Napoleon, D., & Ramanujam, V. (2023). Education 4.0: Curriculum development for the educational framework. In *Industry 4.0 Technologies for Education* (pp. 275–291). Auerbach Publications.
- Navarro-Martinez, O., & Peña-Acuña, B. (2022). Technology usage and academic performance in the Pisa 2018 report. *Journal of New Approaches in Educational Research*, 11(1), 130–145.
- Netolicky, D. M. (2020). School leadership during a pandemic: Navigating tensions. *Journal of Professional Capital and Community*, 5(3/4), 391–395.
- Nguyen, C. D., Huynh, T. N., & Tran, N. H. (2022). Overcoming contextual constraints: implementing classroom pedagogical innovation through teacher leadership. *International journal of leadership in education*, 1–19.
- O’Flaherty, J., & Beal, E. M. (2018). Core competencies and high leverage practices of the beginning teacher: A synthesis of the literature. *Journal of Education for Teaching*, 44(4), 461–478. <https://doi.org/10.1080/02607476.2018.1450826>
- Okoko, J. M. (2023). Focus groups. In *Varieties of qualitative research methods: Selected contextual perspectives* (pp. 191–196). Springer.
- Payne, C. M. (2008). So much reform, so little change. In *Education policy for the 21st century* (pp. 239–278).
- Prestiadi, D., Gunawan, I., & Sumarsono, R. B. (2020). *Role of transformational leadership in education 4.0*. In 6th International conference on education and technology (ICET 2020) (pp. 120–124). Atlantis Press.
- Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex thinking in the framework of education 4.0 and open innovation—A systematic literature review. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1), 4.
- Richard, F.E. (1996). Getting to scale with good educational practice. *Harvard Educational Review*, 66(1), 1–27.
- Rocha, Á., Gonçalves, M. J. A., da Silva, A. F., Teixeira, S., & Silva, R. (2021). Leadership challenges in the context of university 4.0. A thematic synthesis literature review. *Computational and Mathematical Organization Theory*, 1–33.
- Sianturi, M., Lee, J. S., & Cumming, T. M. (2022). Using technology to facilitate partnerships between schools and indigenous parents: A narrative review. *Education and Information Technologies*, 1–24.
- Stukalo, N. (2021). How prepared are we for emergency remote education? Case of Ukraine. In *Emergency remote learning, teaching and leading: Global perspectives* (pp. 159–175). Springer.
- Teo, T., Unwin, S., Scherer, R., & Gardiner, V. (2021). Initial teacher training for twenty-first century skills in the fourth industrial revolution (IR 4.0): A scoping review. *Computers & Education*, 170, 104223.
- Tigre, F. B., Curado, C., & Henriques, P. L. (2023). Digital leadership: A bibliometric analysis. *Journal of Leadership & Organizational Studies*, 30(1), 40–70.

- Townsend, T., & MacBeath, J. (Eds.). (2011). *International handbook of leadership for learning*. Springer.
- Williams, M., & Moser, T. (2019). The art of coding and thematic exploration in qualitative research. *International Management Review*, *15*(1), 45–55.
- Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and stake. *The Qualitative Report*, *20*(2), 134–152. <https://doi.org/10.46743/2160-3715/2015.2102>
- Zhu, C. (2013). Organizational culture and technology-enhanced innovation in higher education. *Technology, Pedagogy and Education*, *24*(1), 65–79. <https://doi.org/10.1080/1475939X.2013.822414>

Chapter 10

Harnessing the Power of Digital Resources in Mathematics Education: The Potential of Augmented Reality and Artificial Intelligence



Xinyue Li  and Rachad Zaki 

Introduction

Digital technologies are reshaping the landscape of education today – teaching and learning now extend beyond traditional school environments, occurring in out-of-class contexts and even virtual spaces, which provides learners with flexible and diverse means of acquiring knowledge. However, the growing availability of digital resources has left teachers, learners, and parents with the daunting task of identifying resources that are beneficial and suited to their specific needs. The education sector often has to work hard to catch up with modern technological developments that are maturing rapidly (Department for Education, 2019); augmented reality (AR) and artificial intelligence (AI) are two representative examples of such technologies. It is important to start examining the resources that already exist and to learn from the current use of these tools and emerging technologies (e.g. AR-based apps; AI-based tools) and from that draw inferences about the potential use and impact of these resources in education, rather than first waiting for a full implementation to take place in educational contexts.

We consider both formal and informal learning contexts in our discussion. In formal learning settings (e.g. schools), a professional teacher or instructor typically facilitates learning. However, with the rapid rise in popularity of blended learning, a face-to-face format is no longer the only option in formal learning contexts – online, distant, or flipped learning can also take place (Taber & Li, 2021). As there is often lack of a physically present professional teacher or instructor in informal

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learning contexts, learners are encouraged to engage in self-directed or self-regulated learning, and this is mostly the case in a home learning environment (HLE).

With a particular focus on mathematics education, this chapter begins by presenting a brief review of literature on the theorisation of technology and a sociocultural framework for the study of digital technology use (sections “[Theorising technology](#)” and “[A sociocultural framework for the study of digital technology use](#)”). It then discusses the definitions, characteristics, and potential implementations of AR and AI resources in mathematics education (section “[Mathematics education meets emerging technologies](#)”). Some key questions are explored:

1. What are the potential implementations of AR in mathematics education?
2. How can AI-based tools be used in mathematics education?
3. How could AR and AI resources be effectively developed to act as tools to mediate mathematics learning?

An important mission of this chapter is to broadly discuss AR and AI resources from both practical and theoretical perspectives and to help inform the design and development of such resources based on psychological and pedagogical perspectives. It also aims to propose principles for designing digital resources (including but not limited to AR and AI) for effective (mathematics) learning (section “[Discussion](#)”). As the content of this chapter is intended to have general relevance, the account offered is generic, rather than focusing on any particular context (e.g. country). Furthermore, the main stakeholders are identified, and a clear description of the potential challenges and ways to overcome them are presented, so that an efficient implementation of any new tool within an educational context can be achieved (section “[Implications](#)”). We conclude by proposing future research directions (section “[Conclusion](#)”).

Theorising Technology

The theorisation of technology is often missing from the canon of research in the field of technology-assisted education, hence the need to address the topic in this chapter. In a systematic review of publications between 2001 and 2011, Oliver (2013) found that there were arguably only ten articles that focused on the study of technology from a theoretical perspective, and most of the attempts had drawn on the idea of *affordance*. Coined by James Gibson, affordance was initially developed in the field of ecological psychology as Gibson argued that “affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill” (1979, p. 127).

To understand how the concept of affordance has been used in the field of educational research, we carried out a systematic review on the Web of Science database using “affordance” and “educational research” as topic (TS = (affordance) *and*

TS = (educational research)), which returned 67 results. We found that the concept of affordance has been adopted to understand technology in several educational contexts, including teaching and learning in early childhood (e.g. Carr, 2000; Jeon et al., 2022), secondary school (e.g. Major et al., 2022), higher education (e.g. Krouska et al., 2022; Lainema et al., 2021), gamification in education (e.g. Lievens & van Daele, 2015, Park & Kim, 2021), AR-based (e.g. Lee & Lee, 2016), and VR-based (e.g. Uz-Bilgin & Thompson, 2022) environments.

Simply put, affordance can be understood as clues that give users hints about how to interact with certain objects; these clues can be explicit (obvious) or implicit (hidden). Therefore, based on Gibson’s theories, many researchers often draw a parallel between affordance and user experience (UX). For example, Pucillo and Cascini (2014) argue that an artefact “affords an experience to a user when presenting certain features that contribute to the fulfilment of a basic psychological need of the user” (p. 169); therefore, affordance is closely related to technology design.

It is argued that affordance-based accounts have positioned technology as the cause of changes in learning (e.g. Oliver, 2011), which is being *technologically deterministic* – a concept posited by Thorstein Veblen, who believed that technology was the agent of social change. However, many researchers argue that there are other factors that drive societal development (e.g. Jacobs & Asokan, 1999); it would therefore be too radical to assume that technology has a position of almost absolute power over the development of society. Therefore, there is a need to develop an alternative account to better understand the use of digital technology in education. One of the critical responses to the beliefs that position technology as a determinant of practice is to theorise technology from social perspectives (Oliver, 2013). This is based on constructivist accounts (Thorpe, 2002) and values the agency of learners, which is absent in the deterministic perspective.

It is argued that Vygotsky’s ideas are relevant to the uptake of digital technologies in learning (Taber & Li, 2021). For example, for Vygotsky, tools play the “mediating role in human reaction and interaction with the world” (Verenikina, 2010, p. 19). Tools can be categorised as external/physical tools (e.g. artefacts, instruments, etc.) and internal/psychological/symbolic tools (e.g. procedures, methods, concepts, etc.): see Fig. 10.1 below. External tools are designed to “manipulate physical objects”, and internal tools can be used by learners to “influence people or themselves” (Verenikina, 2010, p. 19). For the purpose of this chapter, AR and AI resources are theorised as tools.



Fig. 10.1 External and internal tools

A Sociocultural Framework for the Study of Digital Technology Use

Supporting Development: Zone of Proximal Development

In this section we consider Vygotsky's notions of how development can be supported by mediation in a learner's zone of proximal development (ZPD) through *scaffolding* (a form of assistance; see section "[Scaffolding mediated by digital technology](#)" for further discussion). As demonstrated in Fig. 10.2, ZPD is a spatial

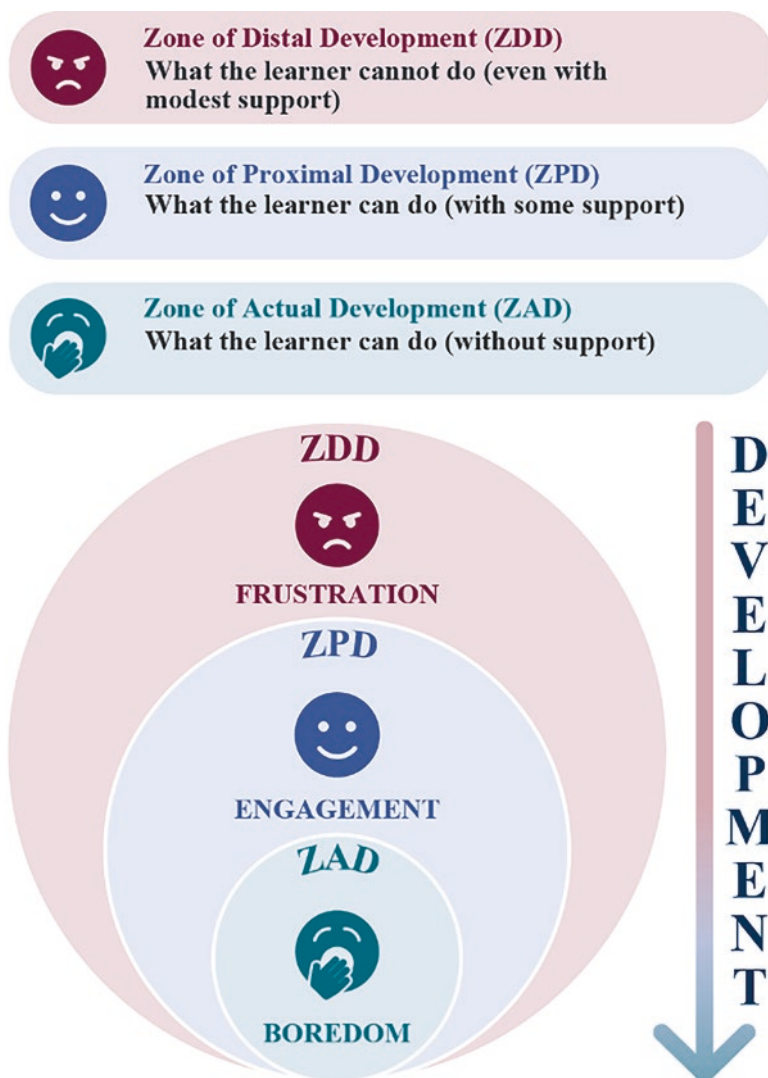


Fig. 10.2 Representation of the ZPD. (Developed from Taber (2018) and Li and Taber (2022))

metaphor which is developed from the zone of actual development (ZAD) – what we have already mastered and can accomplish well without support – and it can be developed into the zone of distal development (ZDD) – what we have no competency in at all and cannot achieve even with guidance or support. These zones are not static – they shift, as learners can move along these dimensions depending on the development of competence (Taber, 2018; Taber & Li, 2021).

A learner who is working in the ZPD aims to develop beyond what they have already mastered, including knowledge and skills, with the help of a *more knowledgeable other* (MKO) (or *more capable other* as used by some researchers). The MKO, who has previously been inducted into aspects of culture not yet available to the learner, is able to mediate between the learner and the aspect of culture (here, some knowledge or skills) that is the focus of the learning (Li & Taber, 2022). For example, teachers can be considered as MKOs in classroom settings. This, however, does not imply that effective learning always occurs when a novice seeks to engage in learning activities with an MKO. For example, suppose a teacher introduces the multiplication table (less formally the times table) for the very first time but immediately moves on to solving complex multiplication problems without giving students the opportunity to understand the basic principles or practise simpler problems. In this case, as there is a lack of sufficient understanding of the task to direct the activity in a productive way, many students would be working in the ZDD – the task is too difficult to be completed without proper instruction or support, and there is no effective scaffolding in place to help students progress from what they already know (ZAD) to the new skills they need to acquire. As a result, effective learning would not occur. Therefore, many researchers have argued that the most effective learning takes place when learners engage in learning activities in their ZPDs (e.g. Barohny, 2019; Taber, 2020). Figure 10.3 shows how a teacher could approach teaching in a way that places students within their ZPDs.

According to the ZPD model, what is initially experienced vicariously by engaging with an MKO on the social (interpersonal) plane is assimilated onto the cognitive (intrapersonal) plane through the learner’s increasing participation. That is, the learner progresses from guided participation (directed by an MKO) to a position where the activity can be self-directed, through scaffolding.

Scaffolding Mediated by Digital Technology

The term *scaffolding* has a long history of being associated with Vygotsky (Cazden, 1979; Wood et al., 1976); however, it is not a term coined by Vygotsky himself (Bodrova et al., 2011), and he did not use this term in his work. Bruner (1975) applied this metaphor in order to understand parent-infant communication to support early language acquisition; Wood et al. (1976) described scaffolding as a form of assistance which “enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his [*sic*] unassisted efforts” (p. 90).

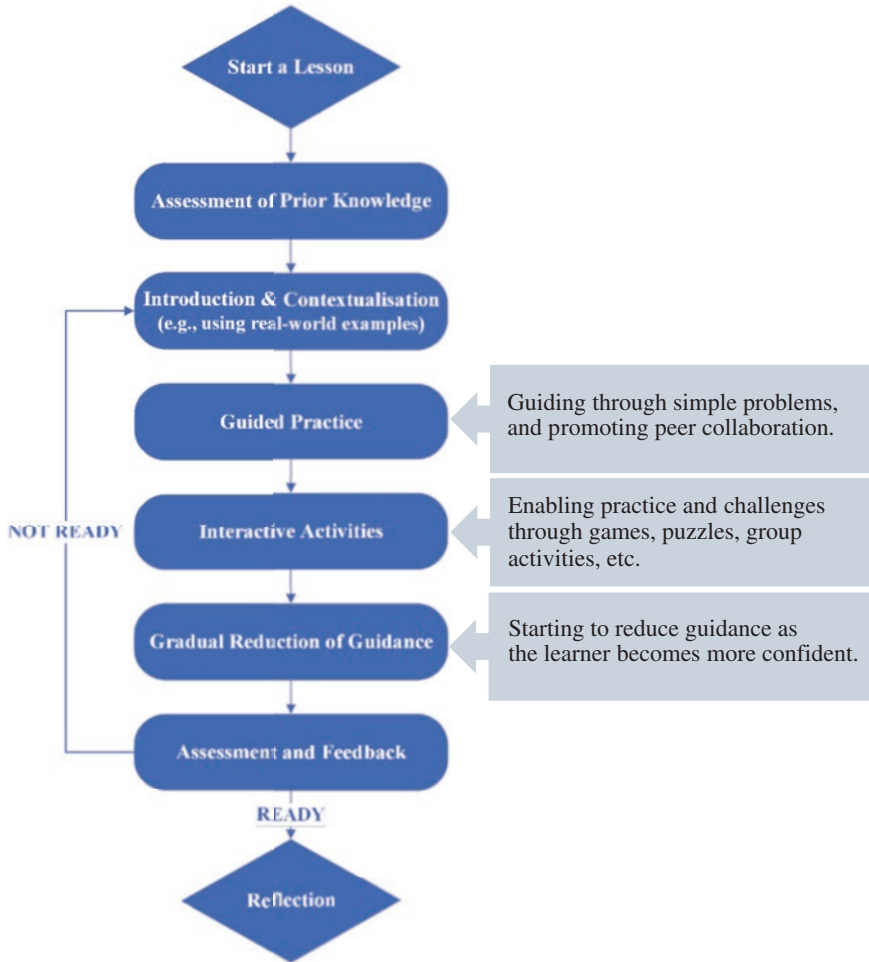


Fig. 10.3 Teaching in the ZPD

Scaffolding cannot be simply understood as offering support; it is argued that the “essential quality of ‘scaffolding’ in all settings must be that it is the provision of guidance and support which is increased or withdrawn in response to the developing competence of the learner” (Mercer, 1995, p. 75). Hence, scaffolding is challenging: dismantling scaffolding too slowly would result in suboptimal development, which then demotivates learning; on the other hand, if scaffolding is withdrawn too quickly, the learner might fail to learn (Taber & Brock, 2018; Zion et al., 2007).

With the rapid development of digital technology, interactions are not limited to teacher-learner (human-human), and scaffolding has been extended to the use of technological tools (Puntambekar & Hubscher, 2005). In technology-enhanced learning contexts, scaffolding can be conceptualised as “the provision of

technology-mediated support to learners as they engage in a specific learning task” (Sharma & Hannafin, 2007, p. 29), and it is argued that technology-enhanced scaffolding can attract and retain learners’ attention (Shute & Miksad, 1997).

In classrooms, mediation in Vygotsky’s model usually involves an adult or an MKO being physically present to guide learners. In addition, teachers can use many technologies as tools, including interactive boards, tablets, and laptops, to present teaching materials, organise scaffolding activities, and help students construct new knowledge. Therefore, the face-to-face interaction enables mediation to happen.

In out-of-class contexts, many digital tools have the potential to scaffold learning, whether or not they are primarily designed for education. For example, with online meeting tools (e.g. Teams, Zoom, etc.), teachers can arrange live lessons with students, which can range from individualised one-to-one lessons to whole-class teaching. Such live meeting tools can be more effective at scaffolding students’ learning than using pre-recorded videos as they can support the kinds of interactivity that turns lessons from just lecturing into interactive teaching and learning. This provides real-time feedback which supports work in the learners’ ZPDs.

Cultural-Historical Activity Theory and Mediation

Activity theory, or cultural-historical activity theory (CHAT), encompasses three principal generations. The first generation expands on Vygotsky’s notion of mediation, focusing on the individual’s perspective. The second generation builds upon Leont’ev’s notion of an activity system, highlighting collective participation. The third generation, developed by Engeström, emphasises the idea of multiple interacting activity systems.

First Generation: Vygotsky’s Cultural-Historical Psychology

Culture and society can be understood as “generative forces behind the very production of human mind” (Clemmensen et al., 2016, p. 611). Vygotsky valued the perspective of humans “as active agents, together with their social environment as a single functional unit in several laboratory studies” (Blayone, 2019, p. 448). One of the fundamental concepts of the CHAT is *activity*, which refers to “a process-as-a-whole, rather than linear sequence of discrete actions” (Foot, 2014, p. 333), and is understood as a “powerful, social, mediated, multi-level, and developing interaction between actors (‘subjects’) and the objective world (‘objects’)” (Clemmensen et al., 2016, p. 611).

Vygotsky founded cultural-historical psychology, which is the basis for CHAT. Figure 10.4 illustrates the simplified version of Vygotsky’s (1978) notions of cultural mediation (inspired by Daniels, 2001, p. 86). This triangle represents Vygotsky’s idea of how cultural artefacts are brought together with human actions. Since cultural and social influences are considered to construct the human mind, tools are culturally and socially constructed. Therefore, a learner can learn new

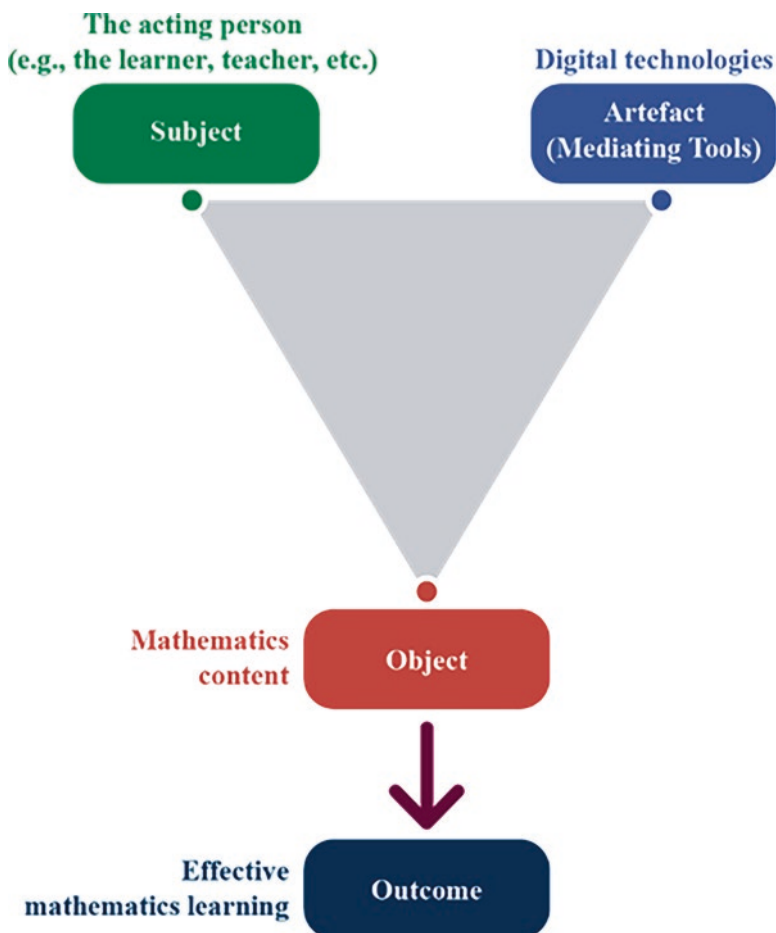


Fig. 10.4 Mediation triangle (the first generation)

things and construct new understanding using external or internal tools to mediate the relationships with social context.

Second Generation: Leont'ev's Activity Hierarchy

One of the limitations of the mediation model discussed above is that it is individually focused. Therefore, the second generation of CHAT moves beyond the individually focused model (see Fig. 10.4 above) to Leont'ev's collective model.

Leontief (1978) portrayed *activity* as a comprehensive and collaborative construct, which should not be mistaken for the commonplace usage of activity in English language (Hasan & Kazlauskas, 2014). In the hierarchical structure, an *activity* resides at the top, superior to the goal-oriented *action* and underlying *Operation* (as illustrated in Fig. 10.5).

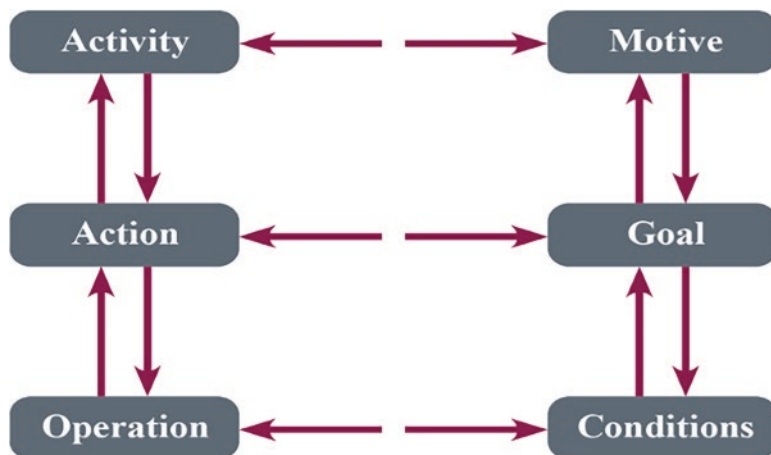


Fig. 10.5 The activity hierarchy of Leont'ev (1978)

Third Generation: Engeström

Based on Vygotsky's foundational work and Leont'ev's extension, Engeström (1987) further developed CHAT by introducing the social and collective perspectives and represented Vygotsky's and Leont'ev's ideas in a visual triangle; see Engeström (1987, p. 78) for the demonstration.

CHAT provides a framework for "understanding transformations in collective practices and organisations" (Engeström et al., 2002, p. 211); it can help explore the use of technology (Issroff & Scanlon, 2002); and it has been widely used in the field of human-computer interaction (Bødker, 1990; Clemmensen et al., 2016; Kaptelinin & Nardi, 2009). Mediation can be directed through engaging in the shared activity (e.g. learning from a teacher who is physically present in front of a learner) or using external tools (e.g. digital technology) in the self-directed learning contexts where learners need to monitor and modify the scaffolding process.

Imagine a hypothetical case: it would be challenging for a young learner who wishes to learn about a cube to engage solely in self-directed activities without any mediation from others (human beings or digital technologies). Even for autodidacts who can master knowledge and skills without formal tutoring in schools, mediation still takes place. However, it may not proceed through the mediation of teachers who are physically present – instead, learners might search for a picture, a description of a cube online, watch a short video lesson, or find AR-based apps on mobile devices to have a better understanding of a cube's structure; the learning process is mediated by these external tools (online lessons, apps, etc.) as well as indirectly by teachers or app developers who provided the resources or supported their development.

Mathematics Education Meets Emerging Technologies

Many emerging technologies which have been widely used in various fields (e.g. entertainment, engineering, architecture, etc.), including 3D printing, robotics, AR, AI, holographic projection, etc., are gradually being made available to teachers, learners, and parents in educational contexts (Taber & Li, 2021). Because these tools have provided immersive, innovative, and groundbreaking experiences in other fields, many teachers, learners, and parents often assume that they can effectively support learning once they are made available in the education sector, without questioning how and why. In the following sections, we discuss the definitions and characteristics of AR as well as AI, propose some potential implementations of AR in mathematics education, and provide an overview of how AI-based tools can be used in the teaching and learning of mathematics. These resources not only provide sources of knowledge but also facilitate the interaction between learners and learning materials.

Augmented Reality

Four Definitions and Characteristics of Augmented Reality

Augmented reality (AR) has been defined by researchers in different fields. For instance, some researchers define AR by two approaches: a broad approach, which refers to “augmenting natural feedback to the operator with simulated cues” (Milgram et al., 1994, p. 283), and a restricted approach, which refers to “a form of virtual reality where the participant’s head-mounted display is transparent, allowing a clear view of the real world” (Milgram et al., 1994, p. 283). In addition, AR is also defined as a “technology” by many researchers (e.g. Klopfer & Sheldon, 2010).

According to Klopfer and Squire (2008), AR can be defined as “a situation in which a real-world context is dynamically overlaid with coherent location or context sensitive virtual information” (p. 205); therefore, AR could offer users immersive experiences where real and virtual worlds are blended (Klopfer & Sheldon, 2010). Hence it is argued that it would be more productive to define AR broadly for educators as this position is not limited to any type of technology (Wu et al., 2013). In general, AR is an interactive experience that provides the opportunity for learners to overlay various forms of information (e.g. visuals, texts, etc.) onto the real world around them.

Software that incorporates AR technology can be divided into two groups: applications with markers (symbolic figures that can be recognised through a camera from multiple points of view which can then be transformed into the virtual information) or trackers and marker-less or tracker-less applications (Carbonell Carrera & Bermejo Asensio, 2017).

AR could (1) help with the visualisation and manipulation of abstract concepts, topics, or knowledge (Kerawalla et al., 2006), for example, an AR app would allow learners to “twist”, enlarge, and reduce a 3D object; (2) support a variety of learning activities in mobile and out-of-class contexts (Squire & Jan, 2007), for example, many AR-based apps can be accessed via smartphones, and this has blurred the boundaries between formal and informal learning; (3) enhance a sense of presence for learners (Bronack, 2011); (4) facilitate learning in 3D perspectives (Arvanitis et al., 2009), for example, students are able to engage with 3D objects to enhance their understanding (Chen et al., 2011); and (5) facilitate game-based learning which can enhance students’ learning motivation (Sotiriou & Bogner, 2008). We propose some potential implementations of AR in mathematics education in the following section.

AR-Enhanced Mathematics Education

AR-powered tools aid in the blending of real-world settings with context-based digital information (Sommerauer & Müller, 2014), allowing users to view virtual objects that are superimposed or composited with the real world. Looking at it from this angle, AR-based tools can facilitate mathematics education.

Spatial visualisation can be understood as “understanding and performing imagined movements of 2D and 3D objects” (Clements, 2004, p. 284). As QR codes and image trackers enable learners to reveal a 3D object by scanning an item using their device’s camera, such as the built-in camera on a smartphone, AR-powered tools can help with visualisation. For example, teachers have the option to print out QR codes and establish various stations around the classroom. Learners can then scan these QR codes to reveal and engage with the 3D objects (e.g. Google Expeditions). In addition, many AR-based apps use surface detection rather than QR codes and image trackers. Learners can scan a flat surface using their device’s camera, and the device will be able to recognise it, resulting in a 3D object being “placed” on that flat surface.

Because of the nature of AR technology, AR-based tools are often employed in the teaching and learning of geometry and spatial skills, and these are also the relatively well-researched topics in educational research. For instance, *Measure* is one of the common apps being studied and used in mathematics education; it is a pre-installed app included for iPhone and iPad. It uses the built-in camera and AR technology to measure the length or area of objects in real-life situations (Apple, 2018). In addition, *GeoGebra* is one of the most well-researched AR-based tools in mathematics education (e.g. Kounlaxay, et al., 2021); it is an interactive application which can be effectively used for teaching and learning in mathematics education.

The potential of AR to facilitate mathematics education is not confined to geometry or spatial skills. Other areas, such as modelling, can also benefit from AR-based teaching and learning methods (Caridade, 2022). We believe that there is a need for more empirical research studies to further explore the expansive potential of AR in mathematics education.

Artificial Intelligence

Definitions and Characteristics of Artificial Intelligence

Artificial intelligence (AI) is an umbrella term for technology capable of performing tasks intelligently. Unlike AR, which is relatively well defined in educational research, various definitions of AI have been proposed by pioneers, experts, researchers, companies, organisations, the media, etc. These definitions include:

The science of making machines do things that would require intelligence if done by men [*sic*]. (Minsky, 1968, p. v).

The use of computer programs that have some of the qualities of the human mind, such as the ability to understand language, recognize pictures, and learn from experience. (Cambridge University Press, 2017).

AI, shorthand for artificial intelligence, defines technologies emerging today that can understand, learn, and then act based on that information. (PWC, 2017, p. 2).

AI generally refers to the ability of machines to exhibit human-like intelligence—for example, solving a problem without the use of hand-coded software containing detailed instructions. (Bughin et al., 2017, p. 7).

AI is the ability of a machine to display human-like capabilities such as reasoning, learning, planning and creativity. (European Parliament, 2023).

Simply put, AI can be understood as the brain for computers, robots, and other smart technologies. Just as students can learn to achieve better grades in examinations, AI can learn to improve at various tasks too. At first, it might not be very good at a specific task, just as when children first learn something new, but over time, as AI keeps learning from data and experience, its performance gets better and better.

Due to the nature of machine learning, AI-powered tools can facilitate learning and teaching in a variety of ways. Some examples are (1) acting as personal tutors by providing immediate personalised feedback; (2) helping learners reflect on learning materials; (3) helping teachers by providing profiles of each learner's current knowledge (ZAD); and (4) gathering information, generating ideas, and providing summaries to help learners establish an understanding of an unfamiliar topic quickly, etc. (Sabzalieva & Valentini, 2023). We provide an overview of how AI-based tools can be used in the teaching and learning of mathematics in the following section.

AI-Enhanced Mathematics Education

Advancements in AI-powered technologies are developing apace during the decade of the 2020s; many AI tools, including ChatGPT (a chatbot developed by OpenAI that is capable of writing articles, suggesting solutions in a variety of disciplines, generating code, and so forth) (OpenAI, 2023a, b), have already raised several opportunities and challenges in the education sector. In this section, we list implications from three perspectives: teaching, teacher-directed learning, and self-directed learning.

Teaching

AI tools can support teachers from many perspectives: (1) AI assistants have the potential to alleviate teachers' workload associated with routine tasks; (2) AI tools can collect and process learner data, empowering teachers with recommendations tailored to their students' individual needs; and (3) AI tools can aid in enhancing teaching practices by fostering reflection, assisting in planning, and promoting continuous improvement (U.S. Department of Education, 2023). For instance, in a mathematics lesson, a teacher could employ AI tools to:

- Generate graphs, images, and visuals – this could assist students in understanding abstract concepts in a more concrete manner.
- Generate questions which can be used to test students' knowledge (e.g. prompt: give me a list of short questions on quadratic functions).
- Generate learning pathways (e.g. make learning pathways for studying multiplication for a student aged 7).
- Generate revision schedules (e.g. prompt: I am helping my students to prepare for a mock test on mathematics next Friday, make me a realistic revision schedule), etc.

Learning (Teacher Directed)

AI tools can assist in finding and filtering information for various applications, thereby supporting the completion of tasks assigned by a teacher in teacher-directed learning contexts (e.g. an essay on a mathematics-related topic). For instance, a learner can employ AI tools to generate initial ideas, which they can refer to in a background research or self-study when drafting an essay on a topic of, for example, the exploration of geometric series in musical instruments. While such tools can be of great help to learners, their use should be guided by a proper understanding of the fact that they are simply a supporting tool and by clear policies to ensure an ethical and logical use of such resources.

Learning (Self-Directed)

From a sociocultural perspective, many AI-powered tools have built-in affordance to act as MKOs, which may compensate for the physical absence of a teacher in self-directed learning contexts (Taber & Li, 2021). For instance, some AI-powered apps equipped with image recognition capabilities can evaluate a learner's problem-solving process simply by having the learner upload a picture to the app; detailed feedback would also be offered. In addition, there are AI assistants which can help with enhancing individualised learning experiences. For example, Amazon Alexa, Siri (Apple), and Cortana (Microsoft) (these are built-in virtual assistants) can

answer questions such as “What is a triangle?”; this would assist learners in developing a basic understanding of unfamiliar knowledge, even without the presence of a human MKO.

Furthermore, this could extend to general topics that might not be part of a mathematics curriculum. For example, if we are interested in magic squares, we could ask an AI tool to “teach” us the basics of this topic. The following prompt was input into GPT-4 (ChatGPT’s successor, released in March 2023): “How to solve a 5*5 magic square puzzle?”. The output obtained was:

A magic square is an arrangement of distinct numbers (i.e., each number is used only once), usually integers, in a square grid, where the numbers in each row, each column, and both main diagonals all add up to the same number, which is called the magic constant.

Here is an algorithm to solve a 5×5 magic square:

1. Start with a 5×5 grid with the cells numbered 1 through 25.
2. Place the number 1 in the center column and the top row.
3. Follow the rule: place each subsequent number in the cell diagonally up and to the right. If a move takes you off the top of the grid, pretend the grid wraps around and place the number at the bottom. If a move takes you off the right edge of the grid, pretend the grid wraps around and place the number on the left side. If a move takes you to an already occupied cell, place the number in the cell directly beneath the previously filled cell.
4. Continue until you’ve placed all 25 numbers.

Here is an example of a 5×5 magic square:

17	24	1	8	15
23	5	7	14	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

In this example, every row, column, and both main diagonals add up to 65.

Bear in mind that there are many other 5×5 magic squares. The algorithm above is just one way to create them. (OpenAI, 2023a, June 21).

Many AI tools can act as personal tutors that can provide immediate and individualised feedback; this can help scaffold and mediate learning in ZPD. As mentioned earlier, scaffolding can be challenging even for a professional teacher, as it is difficult to determine when and how it should be withdrawn; it can be even more challenging for learners who might have a much more limited basis for making professional and critical judgements. Given that machine learning depends on training systems with substantial data, once the AI tool has collected and processed a sufficient amount of data about a learner’s capabilities (e.g. what they can and cannot do), it could theoretically identify the learner’s ZPD. Following this, the AI tool could provide personalised learning materials and propose relevant activities to scaffold and mediate learning, thereby fostering a more effective mathematics learning experience in self-directed learning contexts.

Discussion

Research-Based Principles for Designing Digital Resources for Mathematics Education¹

This section demonstrates a conceptual framework developed from a multiple case study (Li, 2023); based on this framework, principles for designing digital resources for effective mathematics learning are proposed.

Based on the thematic analysis of the empirical data and inspired by CHAT (Engeström, 1987; Engeström, 1999), a conceptual framework was developed (Fig. 10.6, left). The arrows represent the mediation between two factors, while *Content* (subject knowledge) is the base, indicating that any mediation interacts with it.

The pyramid model of the framework (Fig. 10.6, right) highlights these ideas: *Content* is the base, while *Tools* is placed at the apex to showcase that this version of the model represents the mediation of tools among learner, the learning context, the subject content, learning theories (theories that guide the understanding of learners' behaviour, e.g. metacognition), and learning goals. Note that any of the factors in this framework could be placed at the apex of the pyramid.

This framework can have significant implications for the future of mathematics and science education, paving the way for further research and innovation in the field of digital technology-enhanced science, technology, engineering, and mathematics (STEM) education. For instance, it can be implemented for designing pedagogical-based mathematics learning resources that take advantage of emerging technologies and facilitate meaningful mathematics learning experiences. A context, motivation, confidence, agency, and making sense of the world (CMCAM) model is proposed based on this framework; digital resources are suggested to be designed around these elements to make best use of the interactive and immersive environments that they enable to be built.

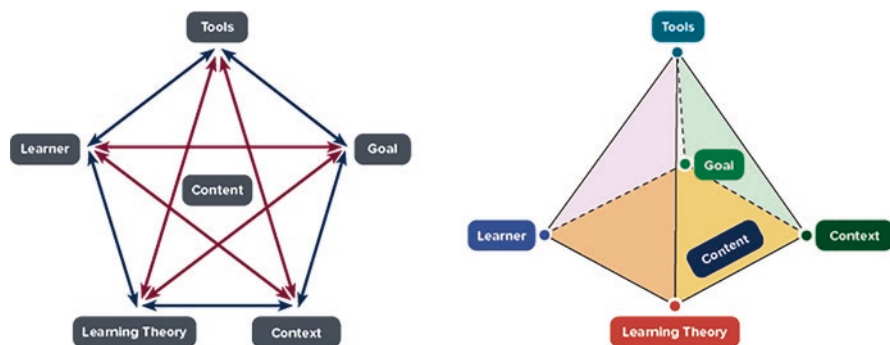


Fig. 10.6 A conceptual framework for digital learning resources design

¹This section is developed from Li, (2023).

Contextualisation (Context)

The widespread availability of technologies and access to the Internet in community and home learning environments have blurred the boundaries between formal and informal learning (Abdullah et al., 2013); however, it is important to note that interactions vary in different learning contexts, hence the need for scaffolding (Taber & Li, 2021). In classrooms, teachers might use a variety of technologies to mediate learning; however, learners often engage in self-directed learning in out-of-class contexts, as a teacher is usually not physically present to monitor and intervene. Therefore, the learning goals (“Goal” in Fig. 10.6) can also be different; e.g. some general goals of the out-of-class learning are (1) to augment activities prescribed by a teacher in the classroom and (2) to follow personal interests (Taber & Li, 2021). Based on these considerations, it is suggested that digital resources should be designed according to specific contexts.

Motivation (Learning Theory)

Learning motivation plays an important role in mathematics and science education; in particular, expectancy-value theory (e.g. Eccles & Wigfield, 2002) and self-determination theory (Ryan & Deci, 2000) are two theoretical approaches that are influential in this field. Specifically, game-based learning is often considered as an effective approach for improving learning motivation (Park et al., 2019); it broadly refers to an educational system with game elements that can trigger motivation for learners (Prensky, 2003). Research studies have suggested that learners would spontaneously engage in learning activities if they were intrinsically motivated (Krapp, 2005; Ryan & Deci, 2000). Therefore, digital resources should be technically attractive (i.e. fun and enjoyable to use) as this would trigger learning motivation. However, the attractiveness of the resources does not guarantee an effective learning outcome; one of the principles for implementing motivational theories in digital resources is the use of rewards, such as performance-contingent rewards (Park et al., 2019).

Confidence (Learning Theory)

Self-efficacy can influence perceptions, performance, and motivation (Bandura, 1997), and Keller (2010) argues that learners can be motivated to learn if they are confident that they can master the knowledge or learning activity and have an expectation of success. Many learners always associate confidence with performance (success or failure) in examinations. The examinations in formal learning contexts, as reflected in the learning with digital resources, are about whether or not learners can accomplish certain tasks (e.g. whether they can pass master levels in a game). Therefore, when designing digital resources, it is important to help learners build confidence through the learning experience (Li, 2023). One of the ways proposed

here is to encourage learners to try, fail, and retry, as “trial and error” is one of the learning strategies suggested by Tsai and Tsai (2003). The importance of learning from failure is also reflected in the “Super Mario effect”, coined by Rober (2019), as learning from failure can improve confidence (McIntyre, 2017).

Agency (Learner)

As discussed in section “**Theorising technology**”, we theorised technology socially as tools; therefore, it aligns well with sociocultural theory as it recognises individual agency (Oliver, 2013). Agency is a complex concept and has been defined by researchers from different perspectives; for instance, it is argued that learner agency bridges motivation and action (Lantolf & Pavlenko, 2014). In addition, Engeström (2006) argues that when a new external is added to the activity system, this would lead to “an aggravated secondary contradiction where some old element ... collides with the new one” (p. 28); this would then trigger the attempt to change, which is also associated with *breaking away*. Breaking away is tentatively defined by Engeström (2006) as “resolving or escaping a contradictory situation by means of constructing mediating artifacts that enable the subjects to master their own actions in a qualitatively new way” (p. 29). Agency is therefore also seen as the ability to change specific actions. According to van Lier (2008), there are three fundamental features of agency: (1) self-regulation, (2) interdependency, which “mediates and is mediated by the sociocultural context”, and (3) “an awareness of the responsibility for one’s own actions vis-à-vis the environment” (p. 172).

Based on these accounts, our view of agency has the following dimensions:

- Metacognition (including self-regulation, awareness of the responsibility for learners’ actions, identification of the ZPD).
- The ability to make decisions and to modify specific actions to facilitate different goals (mediation provided within the resources).
- The ability to engage critically with different resources to achieve individualised learning goals (adjust scaffolding where appropriate).

We suggest that these elements should be considered when designing digital content that is based on a learner-centred approach. For example, a guided learning pathway for learners can be provided, but it is also important to provide opportunities for them to explore the resources themselves: rewards could be given for completing side quests and making decisions in certain scenarios.

Making Sense of the World (Goal)

A major goal of mathematics education today should be to prepare students to apply mathematics in a variety of situations in work and everyday life (Gravemeijer et al., 2017), as whether or not participants can understand the practical value of what they have learnt can influence their learning motivation, experience, and outcome.

Therefore, it is suggested that, where possible, the content/storyline of digital resources should be constructed to reflect how the mathematical and scientific knowledge is relevant to everyday life, so that learners can learn and practise how to apply what they have learnt to new problems and situations and improve their problem-solving skills.

Creating Content for Mathematics Learning with Emerging Technologies

This section presents a list of mathematical topics and skills that can best be scaffolded using emerging technologies, AR and AI, in particular. First, a systematic literature review was conducted on the Web of Science database using “mathematics education”, “augmented reality”, and “AR” as keywords and searched within topic (TS = (mathematics education) and TS = (augmented reality) and TS = (AR)) (returned 139 results), and “mathematics education”, “artificial intelligence”, and “AI” were used as keywords and searched within topic (TS = (mathematics education) and TS = (artificial intelligence) and TS = (AI)) (returned 51 results). Next, mathematics topics were selected based on a meta-analysis of the Cambridge Mathematics Framework (CMF) (see Fig. 10.7). Finally, implications and applications of emerging technologies were mapped to each of the mathematics topics, as presented in Tables 10.1 and 10.2. For the purpose of the present chapter, the keywords were only searched within the topic field. If they were searched within all fields, more results would have been obtained. Therefore, this list is by no means exhaustive. The topics and skills are listed in alphabetical order, and Tables 10.1 and 10.2 are intended to provide a limited number of examples.

The CMF is “a network of mathematical ideas which can be tied to teacher education and training, tasks and assessments. It is designed for the dynamic creation of knowledge maps which serve as representations of conceptual relationships in mathematics learning” (Cambridge Mathematics, n.d.). As demonstrated in Fig. 10.7, there are multiple layers within this framework, including research base (research evidence from literature reviews, consultation with researchers and subject experts); mathematical ideas/experiences (mathematical ideas and relationships

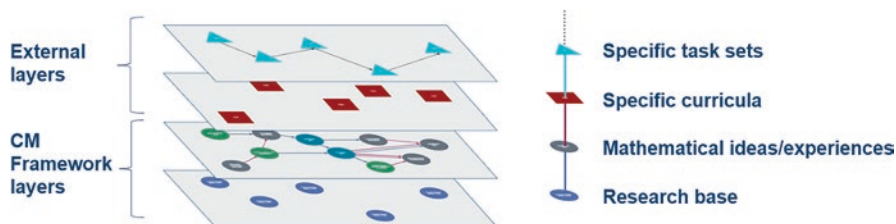


Fig. 10.7 Layers in the Cambridge Mathematics Framework

Table 10.1 AR- and AI-based resources for scaffolding mathematical knowledge

Knowledge	Practical implications for AR and AI integration
Algebra	AR-based technologies can be used to support the development of interactive algebraic simulations, providing dynamic visual representations of algebraic concepts, hence facilitating the learner's conceptual understanding AI-powered personalised tutoring systems can be used to offer tailored guidance and feedback to address individual learning goals
Calculus	AR can help the learner with the visualisation of complex calculus concepts, offering opportunities for the learner to interact with 3D models and graphs to facilitate the concrete comprehension of abstract knowledge AI-powered calculus problem-solvers can be employed to facilitate the practice of solving calculus problems; step-by-step guidance and solutions can be included to suit individualised learning needs
Geometry	AR can be adopted to create an immersive learning environment for geometry, allowing the manipulation of shapes and exploration of spatial relationships, in particular AI-powered tools can assist the learner in geometry by guiding them to build logical arguments and proofs; they can be utilised to help the learner construct logical arguments and proofs with real-time feedback
Statistics	AR can augment real-time data visualisation, enabling interaction with datasets, exploration of statistical concepts, and fostering the development of intuitive understanding AI-driven statistical analysis tools can aid the learner in simplifying data analysis, supporting hypothesis testing, and interpreting results; these tools can make statistics more accessible and inclusive for the learner
Probability theory	AR can generate simulations for enhanced visualisation and experimentation with real and hypothetical scenarios, facilitating the learner's conceptual understanding of probability and their practical applications AI-powered tools, tailored to individual needs, offer explanations, demonstrations, and practice, fostering a deeper and personalised understanding

are represented in the network maps); specific curricula (the use of the CMF to design curricula); and specific task sets (descriptions of classroom activities and/or summative assessment activities).

Implications

Emerging technologies are affecting everyone's daily life and activities. Their impact on education is starting to be more and more apparent, and mathematics is no exception. This chapter showed with theory and practice, mainly through the lens of AR and AI, how limitless the possibilities are and how these technologies could improve teaching and learning in various ways. However, one should also be aware of the many challenges and obstacles that could appear along the way, especially in areas like "human rights and fundamental values; employment and skills; safety, responsibility and liability; transparency and accountability; access to data and personal data protection; fairness and non-discrimination; and open and

Table 10.2 AR- and AI-based resources for scaffolding mathematical skills

Skills	Practical implications for AR and AI integration
Critical thinking	AR-powered interactive simulations can encourage and challenge the user to employ critical thinking and make informed mathematical decisions in digital environments with minimal risk. For example, if a learner using AR simulations miscalculates a bridge's measurements, there is an opportunity for correction and retry. However, if such a mistake is practised in a real-life scenario, it could lead to severe negative consequences AI-generated content might not consistently maintain accuracy. This can act as a catalyst for the learner to scrutinise critically the trustworthiness, credibility, and validity of the source, which is one of the important skills necessitated by today's digital society
Logical thinking and reasoning	AR can be used in the development of logical puzzles, games, and interactive diagrams, which could be fruitful in enhancing the learner's ability to think logically and reason proficiently AI-based tools can provide step-by-step explanations, guiding the learner to apply logical thinking and reasoning skills to solve problems, thereby cultivating the application of these skills
Problem-solving	AR-based tools can be used to develop interactive simulations involving real-world scenarios, enabling the learner to solve various problems to practise and enhance their problem-solving skills AI-based tools can provide adaptive guidance and immediate feedback across mathematical and non-mathematical contexts, allowing the learner to practise, develop, and cultivate their problem-solving skills
Pattern recognition	AR-based simulations can scaffold pattern recognition skills through immersive learning experiences, allowing the learner to visualise and manipulate geometric shapes, graphical patterns, number sequences and other mathematical topics. AI-powered tools, such as adaptive learning platforms, data visualisation tools, and image analysis tools, can be used to facilitate the development of pattern recognition skills through machine learning algorithms, empowering the learner to identify and understand patterns across various domains effectively

inclusive development and diffusion” of new resources (Perset et al., 2018, p. 30), which require clear policies on both national and international levels to address them.

Looking at the current landscape, one should ask the questions: When it comes to education, and mathematics education in particular, are the newly available tools in a place to be trusted and adopted at a large scale? Can we rely on large language models, for example, to provide trustworthy content, solve problems efficiently, and even lead on the teaching front? The answer is clearly: not yet. We will give two examples based on ChatGPT which is the most hyped tool nowadays. Frieder et al. (2023) examined the behaviour of ChatGPT across various datasets that test multiple aspects of mathematical skills. It turned out that “ChatGPT’s ... overall mathematical performance is well below the level of a graduate student” (p. 1) and that it is not yet ready to deliver proofs of a high quality or to be consistent in calculations, even though the answer quality was to an extent positively surprising. Overall, the authors concluded that ChatGPT is “inconsistently bad” (p. 9) when it comes to advanced mathematics. In Shakarian et al. (2023), the authors used ChatGPT with mathematics word problems. They concluded that ChatGPT’s performance varies significantly depending on the amount of work and explanation to be shown, as it

failed 20% of the time when showing work was required compared to 84% when it was not. Other features leading to higher failure rates include the number of unknowns and arithmetic operations.

We answered the question on readiness of new tools for full implementation in education by saying “not yet”, since we believe that the current shortcomings will be addressed as the technologies keep evolving. Meanwhile, all stakeholders should tread with caution while preparing to embrace a new era for education that could become the norm in the very near future.

Stakeholders and Processes

We start by identifying the main stakeholders in the journey of a new technology-based resource in education, that is, technology developers, regulators and policy-makers, education leaders and managers, the society as a whole, instructors and practitioners, and of course learners. The matrix shown in Fig. 10.8 gives a broad overview of the various roles and responsibilities of all contributors from the creation of a new tool up to its adoption in education contexts. Theoretically, stakeholders can participate in more processes than the ones highlighted, but the idea is to focus on key roles and contributions.

It is important to mention that this figure addresses the case of a tool designed for use in an educational context, like in mathematics, and does not necessarily include possible utilisation in general contexts by non-specialised audience, hence the absence of “Society” as a stakeholder in this process in particular. Moreover, the last phase on evaluation would surely lead to continuous improvements in order to reach the desired outcome, as demonstrated in Fig. 10.9.

In the following sections, we will briefly address the role of the different stakeholders and highlight the implications of technological advances on all parties. Our particular focus will be on AI, as it is currently the most promising and talked-about topic and is becoming embedded in all aspects of life, including education, at a fast pace. We will talk about emerging technology in general, zoom in to the education context as a whole, and focus on mathematics for examples and practical contexts.

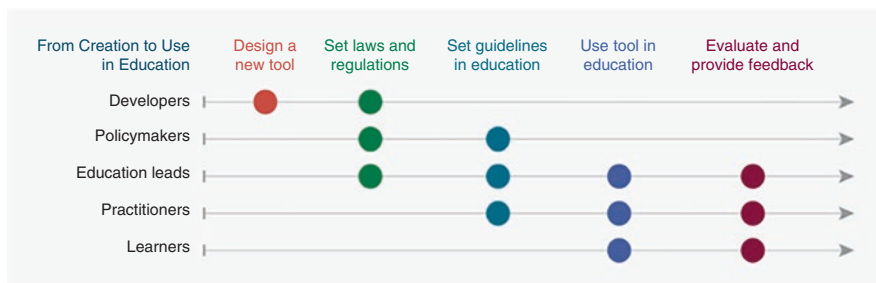


Fig. 10.8 Journey of a new technology tool from creation to use in education

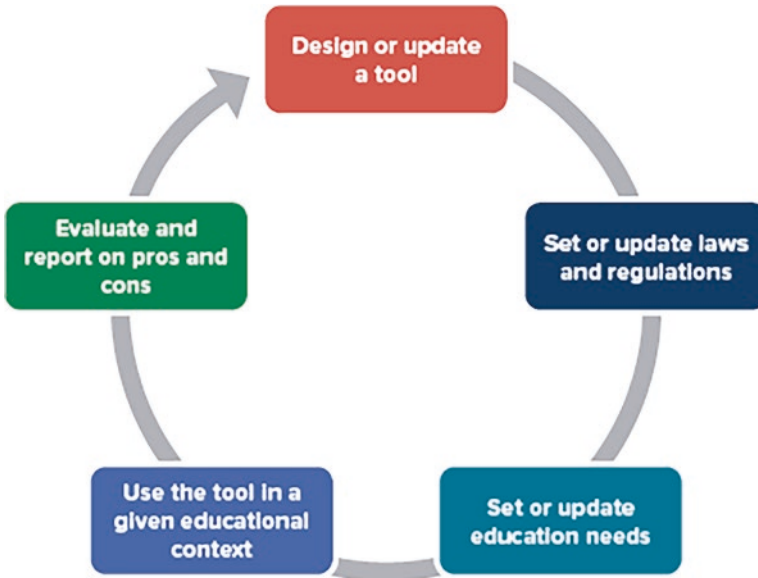


Fig. 10.9 Life cycle of a new technology tool in education

Technology Developers, Designers, and Innovators

As the initiators of new tools and resources, developers should be first aware of the power and authority they have in their hands and act responsibly (Future of Life Institute, 2023). Therefore, it is critical to have a code of ethics that governs their work (Ryan & Stahl, 2020), a code that serves as a moral compass while enabling a proper balance between healthy competition and responsibility towards society. Of course, such a code should ideally govern the whole process from design to methodology to implementation (Griffin et al., 2023) and include all stakeholders, and it is best put in place before any full release of new technology tools that, in the absence of guidelines, can easily get wrongly exploited. Being transparent about the pros and cons, opportunities and challenges, reality and expectations, is another key element (Tu et al., 2016).

Regulators, Policymakers, and Organisations

New regulations are needed to stay in line with the fast advances in technology, and what should start with technology developers should be complemented, fortified, corrected where needed, and legalised by policymakers (Department for Science, Innovation and Technology & Office for Artificial Intelligence, 2023; European

Commission, 2021; Office of Science and Technology Policy, 2022) and major organisations (UNESCO, 2023). Continuous updates will surely be needed to keep up with improvements, and treaties and agreements that govern international implementations should also be put in place.

Education-related policies are also needed to focus on factors that are key in education, ensuring an inclusive approach and one that allows the teaching and learning to thrive when supported or even led by human-created tools. Moreover, it is critical to ensure equilibrium between allowing the use of new technologies to evolve on one hand and the appropriate and safe implementation by the community on the other. In regard to education, all policymakers should work with education leaders to redefine and properly exploit digitalisation and focus on digital literacy (Wong & Kindarji, 2023). They should all strive to address the existing digital divides and prevent further ones (Manolova et al., 2023) and focus on incorporating all the necessary adjustments in curricula from an early age up to high school (Bellas et al., 2023; Su et al., 2023; UNESCO, 2022) while monitoring inclusivity, transparency, and cultural specificities. The structure of the schooling system is hence to be reviewed, and the traditional approach to subjects, examinations, progression, and other elements of our existing schooling systems should be revamped.

It is important at this level to highlight the significance of investing in research and development (R&D) to help guide any policies and to “promote responsible innovation and advance solutions to the challenges that other sectors will not address on their own. This includes R&D to leverage AI to tackle large societal challenges and develop new approaches to mitigate AI risks” (Select Committee on Artificial Intelligence, 2023, p. vii).

Looking at all the above, how should policymakers (like ministries of education) approach mathematics? Will mathematics remain a separate subject, for example? Should computer science become an integral part of a modern mathematics curriculum? Should data literacy be given a wider scope? Can new technologies eliminate the vertical divisions that still exist between most areas, despite the multiple attempts made to popularise STEM and all its derivatives? What about a new literacy pact (linguistic, digital, mathematical, scientific, artistic, and social) that brings everything together for the learners of today and tomorrow? These are just some of the questions which require answers, to be addressed with the help of education institutions and practitioners.

Education Entities’ Leaders and Managers

With the development of a multitude of tools and resources, it falls on education leads (directors, principals, department heads, etc.), in consultation with their teaching bodies, to guide and support the selection and integration of new technologies in their institutions’ offerings and, if they see in them a need or a success factor, to lead on deciding how to incorporate them into their overall future vision (Tyson &

Sauers, 2021). They could also study how new technologies can assist them in their roles and responsibilities. Overall, decisions should be made after a clear analysis of what is available vs what is needed; what is suitable for the institution's context and vision; what is possible from a financial perspective; and what will be welcomed by and useful for instructors and learners who will be the end users and will need to be well aware of, and later well trained in, using any new tool.

In many cases, curricula and instruction models will need to be adjusted as highlighted before, and the same applies to assessment and professional learning approaches, and it is the responsibility of these leaders to ensure all is done properly under the umbrella of general education policies and guidelines set by authorities. Moreover, guaranteeing accessibility of these tools and ensuring an inclusive approach are key elements in the process.

Society as a Whole, Including Parents

The impact of technology on societies has been widely considered in the literature, and this applies in particular to AI since its infancy. In Firschein et al. (1973), the authors discussed possible future societal implications of AI, including the decreased need for human interaction, the elimination of human-only activities, the introduction of jobs that are not feasible by humans only, the automation of processes, the reduced cost of many mundane activities, and more. We are currently living and experiencing all of these phenomena. These ideas, combined with many potential threats, have been heavily discussed, and while there is a need to be cautious, the main message is not necessarily to worry about technologies but rather to be ready to embrace changes, as there is no stopping the proliferation of new innovations. A rule of thumb is for people to become familiar with the basics of the new technologies, understand their pros and cons, and before taking sides, be aware that what is working and “trending” in a certain context and community might not work in another. Eventually, this should be part of the development of what can potentially be labelled a good tech-savvy society, where everyone participates, both in the public and private sector, similar to the “good AI society” highlighted in Cath et al. (2018, p. 505).

As for education and specialised contexts like with mathematics, it is not expected from everyone to be an expert or to participate in the implementation of new tools (as mentioned in Fig. 10.6), but many can play important supporting roles, such as parents ensuring, as much as possible, proper access for their children to the needed resources and to a suitable environment for using the new tools and that their children's progress is being well monitored over time. Since most of the usage of modern technological tools happens out of the classroom (mostly at home) and without the supervision of instructors, having oversight of the time investment and overall progress of children is not to be taken lightly.

Instructors and Practitioners

While new technologies might feel like a threat at times, and while many are hailing the introduction of adaptive tutoring systems, it is important to keep practitioners and instructors at the core of the teaching and learning process and “always center educators (ACE)” as highlighted in *Artificial Intelligence and the Future of Teaching and Learning* (Office of Educational Technology, 2023, p. 23). The same publication also makes the following recommendations: “1) Emphasize humans in the loop; 2) Align AI models to a shared vision for education; 3) Design using modern learning principles; 4) Prioritize strengthening trust; 5) Inform and involve educators; 6) Focus R&D on addressing context and enhancing trust and safety; and 7) Develop education-specific guidelines and guardrails” (Office of Educational Technology, 2023, pp. 53–60). Furthermore, training all educators is vital to ensure they stay up to date with technological advances, knowing that students, even at a younger age, tend to be more open to welcoming these innovations. This should include the scientific component next to the ways for working in tandem with new technologies. Moreover, teaching and assessment methods must also be adjusted to have enough room for technology, and while this could happen at an institutional level, instructors should adapt their approaches to meet the new trends, always keeping in mind the best interests of their students. Throughout the process, the well-being of teachers should be a priority, as any new tool should provide them with a supporting resource for success and improvement rather than being a hurdle on the road of improving.

As several AR- and AI-powered tools are now available for mathematics and are being used more and more by practitioners in formal and informal settings, preparing students, as needed, for the idea of using more technological tools and how to use them remains a key component for the system to run smoothly. This falls to a large extent on instructors, who should also remain aware of students’ use of these tools to ensure their ethical and efficient incorporation in the learning process.

Learners and End Users in Education

It is important for every learner to understand well the overall functionalities of any tool they might be using, to fathom its strengths and weaknesses, and to ensure they are using it ethically and professionally. Eventually, these new tools should serve as supporting resources that strengthen the learning process rather than being a replacement of the student’s role in solving questions or writing essays. Using a technology tool could also complement interactions with instructors and peers, especially when circumstances do not allow their physical presence, but it should not be seen as a replacement for human interaction. Furthermore, as adaptivity is to be considered in any learning environment, emerging technologies are proving to be a great ally; AI, for example, “may improve a technology’s ability to meet students where they are,

build on their strengths, and grow their knowledge and skills” (Office of Educational Technology, 2023, p. 18).

When it comes to education, and mathematics education in particular, many adaptive AI-powered platforms currently exist to support educators and learners from an early age up to high school, with multiple reports discussing their impact on students’ learning and improvement (Craig et al., 2013; Geary et al., 2021). Gamification is another rapidly growing area in the field of education that assists in the learning process, and emerging technologies are playing more central roles in improving the game features.

Conclusion

Contributions

Many emerging technologies have already changed our perception of reality. As infrastructure develops, it is possible that more immersive real-time interaction will be offered, either directly or through the construction of learning resources. The present chapter contributes to this field by proposing research-based principles for designing AR- and AI-based resources for educational purposes in general and mathematics education in particular. We need to respond to these technologies as soon as possible – to understand what the implications and possibilities will be and how these tools can be introduced practically and ethically into the teaching and learning of mathematics in formal and informal contexts at all levels.

Recommendations for Further Research

Although many research studies have suggested that an increasing amount of screen time could lead to negative physical (lack of exercise) and mental (anxiety and depression) well-being to shorter attention spans and a decline in cognitive skills (including reading and writing skills), there has been relatively less focus on social well-being. Social well-being refers to a sense of belonging to a community and the ability to establish positive relationships with other people in society (Boston University, n.d.); it remains unclear how young people’s engagement in the virtual environment might influence their social well-being in the real world. Therefore, more research is needed from this perspective, in particular, to explore the relationship between digital technologies and young people’s development of self-awareness, interpersonal collaboration, and communication (e.g. deep listening and thinking).

In addition, we are clearly stepping into a more immersive digital society where mixed reality (MR) is becoming the new norm, Apple Vision Pro and Meta Quest 3

being two recent examples. Because of the scope of the present chapter, only AR and AI are considered. However, we want to point out that more empirical research studies are needed to explore the potential use of extended reality (XR) in educational contexts. The concept of XR, which encompasses AR, virtual reality (VR), and MR, has been prevalent ever since the notion of fabricating alternative realities became a popular theme in science fiction (Lai & Cheong, 2022). In the light of recent technological advancements, the utilisation of these tools is no longer “fictional” that can only be seen in literary works, TV dramas, and films. Indeed, XR technologies have impacted our society in various ways; they are constantly expanding into gaming (e.g. *Roblox*), sports (e.g. the virtual *Etihad Stadium*), exhibitions (e.g. *Expo Dubai Xplorer*), social gatherings (e.g. *Zepeto*), healthcare (e.g. telemedicine consultations), and training (e.g. the multi-user virtual application for forklift driving training developed by Turku University of Applied Science). A broad spectrum of stakeholders (e.g. learners, teachers, practitioners, curriculum designers, etc.) needs to be prepared for such a swift technological evolution, and this applies to the mathematics education sector which might not be fully ready for this advancement. There is a gap in the literature and therefore an urgent need for more empirical research to understand what the implications and possibilities of XR are for mathematics education and how they could be practically introduced into the teaching and learning of mathematics.

References

- Abdullah, M. R. T. L., Hussin, Z., Asra, Z., & Zakaria, A. R. (2013). mLearning scaffolding model for undergraduate English language learning: Bridging formal and informal learning. *Turkish Online Journal of Educational Technology*, 12(2), 217–233.
- Apple. (2018). *Augmented reality in education: Lesson ideas*. Apple <https://www.apple.com/uk/education/docs/ar-in-edu-lesson-ideas.pdf>
- Arvanitis, T. N., Petrou, A., Knight, J. F., Savas, S., Sotiriou, S., Gargalakos, M., & Gialouri, E. (2009). Human factors and qualitative pedagogical evaluation of a mobile augmented reality system for science education used by learners with physical disabilities. *Personal and Ubiquitous Computing*, 13, 243–250. <https://doi.org/10.1007/s00779-007-0187-7>
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.
- Barohny, E. (2019). The zone of proximal development as an overarching concept: A framework for synthesizing Vygotsky’s theories. *Educational Philosophy and Theory*, 51(1), 18–30. <https://doi.org/10.1080/00131857.2017.1421941>
- Bellas, F., Guerreiro-Santalla, S., Naya, M., & Duro, R. J. (2023). AI curriculum for European high schools: An embedded intelligence approach. *International Journal of Artificial Intelligence in Education*, 33, 399–426. <https://doi.org/10.1007/s40593-022-00315-0>
- Blayone, T. J. B. (2019). Theorising effective uses of digital technology with activity theory. *Technology, Pedagogy and Education*, 28(4), 447–462. <https://doi.org/10.1080/01475939X.2019.1645728>
- Bødker, S. (1990). *Through the interface: A human activity approach to user interface design*. Routledge.
- Bodrova, E., Leong, D. J., & Akhutina, T. V. (2011). When everything new is well-forgotten old: Vygotsky/Luria insights in the development of executive functions. *New Directions for Child and Adolescent Development*, 2011(133), 11–28. <https://doi.org/10.1002/cd.301>

- Boston University. (n.d.). *Social wellbeing*. <https://www.bu.edu/studentwellbeing/what-is-wellbeing/social-wellbeing/>
- Bronack, S. C. (2011). The role of immersive media in online education. *The Journal of Continuing Higher Education*, 59(2), 113–117. <https://doi.org/10.1080/07377363.2011.583186>
- Bruner, J. S. (1975). The ontogenesis of speech acts. *Journal of Child Language*, 2(1), 1–19. <https://doi.org/10.1017/S0305000900000866>
- Bughin, J., Hazan, E., Ramaswamy, S., Chui, M., Allas, T., Dahlström, P., Henke, N., & Trench, M. (2017). *Artificial intelligence: The next digital frontier?* McKinsey Global Institute.
- Cambridge Mathematics. (n.d.). *Key terms in framework documentation*. <https://www.cambridge-maths.org/research/key-terms-in-framework-documentation/>
- Cambridge University Press. (2017). Artificial intelligence. In *Cambridge academic content dictionary*.
- Carbonell Carrera, C., & Bermejo Asensio, L. A. (2017). Augmented reality as a digital teaching environment to develop spatial thinking. *Cartography and Geographic Information Science*, 44(3), 259–270. <https://doi.org/10.1080/15230406.2016.1145556>
- Caridade, C. M. R. (2022). GeoGebra augmented reality: Ideas for teaching and learning math. In F. Yilmaz, A. Queiruga-Dios, M. J. Santos Sánchez, D. Rasteiro, V. Gayoso Martínez, & J. Martín Vaquero (Eds.), *Mathematical methods for engineering applications. ICMASE 2021* (Springer proceedings in mathematics & statistics) (Vol. 384, pp. 235–244). Springer. https://doi.org/10.1007/978-3-030-96401-6_22
- Carr, M. (2000). Technological affordance, social practice and learning narratives in an early childhood setting. *International Journal of Technology and Design Education*, 10, 61–80. <https://doi.org/10.1023/A:1008986002620>
- Cath, C., Wachter, S., Mittelstadt, B., Taddeo, M., & Floridi, L. (2018). Artificial intelligence and the ‘good society’: The US, EU, and UK approach. *Science and Engineering Ethics*, 24, 505–528.
- Cazden, C. (1979). *Peekaboo as an instructional model: Discourse development at home and at school* (Papers and reports on child language development, No. 17, pp. 1–29). Stanford University, Department of Linguistics. <https://eric.ed.gov/?id=ED191274>
- Chen, Y. C., Chi, H. L., Hung, W. H., & Kang, S. C. (2011). Use of tangible and augmented reality models in engineering graphics courses. *Journal of Professional Issues in Engineering Education & Practice*, 137(4), 267–276. [https://doi.org/10.1061/\(ASCE\)EI.1943-5541.0000078](https://doi.org/10.1061/(ASCE)EI.1943-5541.0000078)
- Clements, D. H. (2004). Geometric and spatial thinking in early childhood education. In D. H. Clements, J. Sarama, & A. M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 267–297). Routledge.
- Clemmensen, T., Kaptelinin, V., & Nardi, B. (2016). Making HCI theory work: An analysis of the use of activity theory in HCI research. *Behaviour and Information Technology*, 35(8), 608–627. <https://doi.org/10.1080/0144929X.2016.1175507>
- Craig, S. D., Hu, X., Graesser, A. C., Bargagliotti, A. E., Sterbinsky, A., Cheney, K. R., & Okwumabua, T. (2013). The impact of a technology-based mathematics after-school program using ALEKS on student’s knowledge and behaviors. *Computers & Education*, 68, 495–504. <https://doi.org/10.1016/j.compedu.2013.06.010>
- Daniels, H. (2001). *Vygotsky and pedagogy*. Routledge.
- Department for Education. (2019). *Realising the potential of technology in education: A strategy for education providers and the technology industry*. <https://www.gov.uk/government/publications/realising-the-potential-of-technology-in-education>
- Department for Science, Innovation and Technology & Office for artificial intelligence. (2023). *AI regulation: A pro-innovation approach*. <https://www.gov.uk/government/publications/ai-regulation-a-pro-innovation-approach>
- Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53(1), 109–132. <https://doi.org/10.1146/annurev.psych.53.100901.135153>
- Engeström, Y. (1987). *Learning by expanding*. Cambridge University Press.

- Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R. Punamäki (Eds.), *Perspectives on activity theory* (pp. 19–38). Cambridge University Press.
- Engeström, Y. (2006). Development, movement and agency: Breaking away into mycorrhizae activities. In K. Yamazumi (Ed.), *Building activity theory in practice: Toward the next generation* (CHAT technical reports #1). Centre for Human Activity Theory/Kansai University.
- Engeström, Y., Engeström, R., & Suntuio, A. (2002). Can a school community learn to master its own future? An activity-theoretical study of expansive learning among middle school teachers. In G. Wells & G. Claxton (Eds.), *Learning for life in the 21st century: Sociocultural perspectives on the future of education* (pp. 211–224). Blackwell. <https://doi.org/10.1002/9780470753545.ch16>
- European Commission. (2021). *Regulatory framework proposal on artificial intelligence*. <https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai>
- European Parliament. (2023, June 6). *What is artificial intelligence and how is it used?* <https://www.europarl.europa.eu/news/en/headlines/society/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used>
- Firschein, O., Fischler, M. A., Coles, L. S., & Tenenbaum, J. M. (1973). *Forecasting and assessing the impact of artificial intelligence on society*. In IJCAI'73: Proceedings of the 3rd international joint conference on artificial intelligence (pp. 105–120). Morgan Kaufmann Publishers. <https://dl.acm.org/doi/10.5555/1624775.1624789>
- Foot, K. A. (2014). Cultural-historical activity theory: Exploring a theory to inform practice and research. *Journal of Human Behavior in the Social Environment*, 24(3), 329–347. <https://psycnet.apa.org/doi/10.1080/10911359.2013.831011>
- Frieder, S., Pinchetti, L., Chevalier, A., Griffiths, R.-R., Salvatori, T., Lukaszewicz, T., Petersen, P. C., & Berner, J. (2023). *Mathematical capabilities of ChatGPT*. arXiv:2301.13867.
- Future of Life Institute. (2023, March 22). *Pause giant AI experiments: An open letter*. <https://futureoflife.org/open-letter/pause-giant-ai-experiments/>
- Geary, D. C., Human-Computer Interaction Institute, & Educational Testing Service. (2021). *Preparation for success in algebra: Exploring math education relationships by analyzing large data sets (EMERALDS)*. Student Achievement Partners. <https://achievethecore.org/file/6020>
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Houghton Mifflin Harcourt.
- Gravemeijer, K., Stephan, M., Julie, C., Lin, F. L., & Ohtani, M. (2017). What mathematics education may prepare students for the society of the future? *International Journal of Science and Mathematics Education*, 15, 105–123. <https://doi.org/10.1007/s10763-017-9814-6>
- Griffin, T. A., Green, B. P., & Welie, J. V. M. (2023). The ethical agency of AI developers. *AI and Ethics*, 2023, 1–10. <https://doi.org/10.1007/s43681-022-00256-3>
- Hasan, H., & Kazlauskas, A. (2014). Activity theory: Who is doing what, why and how. In H. Hasan (Ed.), *Being practical with theory: A window into business research* (pp. 9–14). University of Wollongong. <https://ro.uow.edu.au/buspapers/403>
- Issroff, K., & Scanlon, E. (2002). Educational technology: The influence of theory. *Journal of Interactive Media in Education*, 2002(2), 6. <https://doi.org/10.5334/2002-6>
- Jacobs, G., & Asokan, N. (1999). Towards a comprehensive theory of social development. In *Human choice*. World Academy of Art & Science.
- Jeon, J., Lee, S., & Choe, H. (2022). Enhancing EFL pre-service teachers' affordance noticing and utilizing with the synthesis of qualitative evidence strategies: An exploratory study of a customizable virtual environment platform. *Computers & Education*, 190, 104620. <https://doi.org/10.1016/j.compedu.2022.104620>
- Kaptelinin, V., & Nardi, B. A. (2009). *Acting with technology: Activity theory and interaction design*. MIT Press.
- Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. Springer.
- Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). “Making it real”: Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality*, 10, 163–174. <https://doi.org/10.1007/s10055-006-0036-4>

- Klopfer, E., & Sheldon, J. (2010). Augmenting your own reality: Student authoring of science-based augmented reality games. *New Directions for Youth Development*, 2010(128), 85–94. <https://doi.org/10.1002/yd.378>
- Klopfer, E., & Squire, K. (2008). Environmental detectives – The development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development*, 56(2), 203–228.
- Kounlaxay, K., Shim, Y., Kang, S. J., Kwak, H. Y., & Kim, S. K. (2021). Learning media on mathematical education based on augmented reality. *KSI Transactions on Internet and Information Systems (TIIS)*, 15(3), 1015–1029. <https://doi.org/10.3837/tiis.2021.03.011>
- Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction*, 15(5), 381–395. <https://doi.org/10.1016/j.learninstruc.2005.07.007>
- Krouska, A., Troussas, C., & Sgouropoulou, C. (2022). Mobile game-based learning as a solution in COVID-19 era: Modeling the pedagogical affordance and student interactions. *Education and Information Technologies*, 27, 229–241. <https://doi.org/10.1007/s10639-021-10672-3>
- Lai, J. W., & Cheong, K. H. (2022). Adoption of virtual and augmented reality for mathematics education: A scoping review. *IEEE Access*, 10, 13693–13703. <https://doi.org/10.1109/ACCESS.2022.3145991>
- Lainema, K., Syyänimaa, K., Lainema, T., & Hämäläinen, R. (2021). Organizing for collaboration in simulation-based environments: An affordance perspective. *Journal of Research on Technology in Education*, 55(2), 307–323. <https://doi.org/10.1080/15391523.2021.1962451>
- Lantolf, J. P., & Pavlenko, A. (2014). (S)econd (L)anguage (A)ctivity theory: Understanding second language learners as people. In M. Breen (Ed.), *Learner contributions to language learning* (pp. 141–158). Routledge.
- Lee, W. H., & Lee, H. K. (2016). The usability attributes and evaluation measurements of mobile media AR (augmented reality). *Cogent Arts & Humanities*, 3(1), 1241171. <https://doi.org/10.1080/23311983.2016.1241171>
- Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Prentice-Hall.
- Li, X. (2023). *Transformative implications and evidence-based principles for creating content for mathematics learning in the metaverse*. In Proceedings of the 15th international conference on education and new learning technologies, EDULEARN 23 (pp. 1994–2003). IATED. <https://doi.org/10.21125/edulearn.2023.0602>.
- Li, X., & Taber, K. S. (2022). The future of interaction: Augmented reality, holography and artificial intelligence in early childhood science education. In M. Kalogiannakis & S. Papadakis (Eds.), *STEM, robotics, Mobile apps in early childhood and primary education* (pp. 415–442). Springer. https://doi.org/10.1007/978-981-19-0568-1_18
- Lievens, J., & Van Daele, T. (2015). *Touch teach learn. Unlocking the potential of touch enabled mobile devices for higher education*. In 9th International technology, education and development conference (INTED) proceedings (pp. 5298–5304). IATED.
- Major, L., Smørðal, O., Warwick, P., Rasmussen, I., Cook, V., & Vrikki, M. (2022). Investigating digital technology's role in supporting classroom dialogue: Integrating enacted affordance into analysis across a complex dataset. *International Journal of Research & Method in Education*, 46(1), 37–55. <https://doi.org/10.1080/1743727X.2022.2032632>
- Manolova, M., Sheombar, H., & Surana, J. (Eds.) (2023). *The digital compact consultation. Digital literacy: The great divide*. UN. https://www.un.org/techenvoy/sites/www.un.org/techenvoy/files/GDC-submission_Digital-National-Alliance-Bulgaria.pdf.
- McIntyre, R. (2017, September 17). *Learn from failures to boost your self-confidence*. LinkedIn. <https://www.linkedin.com/pulse/learn-from-failures-boost-your-self-confidence-ron-mcintyre>.
- Mercer, N. (1995). *The guided construction of knowledge: Talk amongst teachers and learners*. Multilingual Matters.
- Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). *Augmented reality: A class of displays on the reality-virtuality continuum*. In Proceedings of SPIE: Telemanipulator and telepresence technologies (Vol. 2351, pp. 282–292).
- Minsky, M. (Ed.). (1968). *Semantic information processing*. MIT Press.

- Office of Educational Technology. (2023). *Artificial intelligence and future of teaching and learning: Insights and recommendations*. U.S. Department of Education. <https://www2.ed.gov/documents/ai-report/ai-report.pdf>.
- Office of Science and Technology Policy. (2022). *Blueprint for an AI bill of rights*. The White House. <https://www.whitehouse.gov/ostp/ai-bill-of-rights/>
- Oliver, M. (2011). Technological determinism in educational technology research: Some alternative ways of thinking about the relationship between learning and technology. *Journal of Computer Assisted Learning*, 27(5), 373–384. <https://doi.org/10.1111/j.1365-2729.2011.00406.x>
- Oliver, M. (2013). Learning technology: Theorising the tools we study. *British Journal of Educational Technology*, 44(1), 31–43. <https://doi.org/10.1111/j.1467-8535.2011.01283.x>
- OpenAI. (2023a). *GPT-4* (June 21 version) [Large language model]. <https://chat.openai.com/>
- OpenAI. (2023b). *ChatGPT* (September 29 version) [Large language model]. <https://chat.openai.com/>
- Park, S., & Kim, S. (2021). Leaderboard design principles to enhance learning and motivation in a gamified educational environment: Development study. *JMIR Serious Games*, 9(2), e14746. <https://doi.org/10.2196/14746>
- Park, J., Kim, S., Kim, A., & Mun, Y. Y. (2019). Learning to be better at the game: Performance vs. completion contingent reward for game-based learning. *Computers & Education*, 139, 1–15. <https://doi.org/10.1016/j.compedu.2019.04.016>
- Perset, K., Nishigata, N., & Carblanc, A. (2018). *Artificial intelligence in society: Phase 1. Directorate for Science, Technology and Innovation Committee on Digital Economy Policy*. OECD.
- Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment*, 1(1), 21. <https://doi.org/10.1145/950566.950596>
- Pucillo, F., & Cascini, G. (2014). A framework for user experience, needs and affordances. *Design Studies*, 35(2), 160–179. <https://doi.org/10.1016/j.destud.2013.10.001>
- Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist*, 40(1), 1–12. https://doi.org/10.1207/s15326985Sep4001_1
- PWC. (2017). *Bot.Me: A revolutionary partnership. How AI is pushing man and machine closer together*. https://www.pwc.com/it/it/publications/assets/docs/PwC_botme-booklet.pdf
- Rober, M. (2019). *The super Mario effect: Tricking your brain into learning more*. TEDxPenn. https://ted.com/talks/mark_rober_the_super_mario_effect_tricking_your_brain_into_learning_more?language=en.
- Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, 25(1), 54–67. <https://doi.org/10.1006/ceps.1999.1020>
- Ryan, M., & Stahl, B. C. (2020). Artificial intelligence ethics guidelines for developers and users: Clarifying their content and normative implications. *Journal of Information, Communication and Ethics in Society*, 19(1), 61–86. <https://doi.org/10.1108/JICES-12-2019-0138>
- Sabzalieva, E., & Valentini, A. (2023). *ChatGPT and artificial intelligence in higher education: Quick start guide*. UNESCO. https://www.iesalc.unesco.org/wp-content/uploads/2023/04/ChatGPT-and-Artificial-Intelligence-in-higher-education-Quick-Start-guide_EN_FINAL.pdf
- Select Committee on Artificial Intelligence. (2023). *National artificial intelligence research and development strategic plan: 2023 update*. National Science and Technology Council. <https://www.whitehouse.gov/wp-content/uploads/2023/05/National-Artificial-Intelligence-Research-and-Development-Strategic-Plan-2023-Update.pdf>
- Shakarian, P., Koyyalamudi, A., Ngu, N., & Mareedu, L. (2023). An independent evaluation of ChatGPT on mathematical word problems (MWP). In A. Martin, K. Hinkelmann, H.-G. Fill, A. Gerber, D. Lenat, R. Stolle, & F. van Harmelen (Eds.), *Proceedings of the AAAI 2023 spring symposium on challenges requiring the combination of machine learning and knowledge engineering (AAAI-MAKE 2023)*. AAAI. <https://arxiv.org/abs/2302.13814>

- Sharma, P., & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments*, 15(1), 27–46. <https://doi.org/10.1080/10494820600996972>
- Shute, R., & Miksad, J. (1997). Computer assisted instruction and cognitive development in pre-schoolers. *Child Study Journal*, 27(3), 237–253. <https://eric.ed.gov/?id=EJ554378>
- Sommerauer, P., & Müller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. *Computers and Education*, 79, 59–68. <https://doi.org/10.1016/j.compedu.2014.07.013>
- Sotiriou, S., & Bogner, F. X. (2008). Visualizing the invisible: Augmented reality as an innovative science education scheme. *Advanced Science Letters*, 1(1), 114–122. <https://doi.org/10.1166/asl.2008.012>
- Squire, K. D., & Jan, M. (2007). Mad City mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology*, 16, 5–29. <https://doi.org/10.1007/S10956-006-9037-Z>
- Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial intelligence (AI) literacy in early childhood education: The challenges and opportunities. *Computers and Education: Artificial Intelligence*, 4, 100124. <https://doi.org/10.1016/j.caeai.2023.100124>
- Taber, K. S. (2018). Scaffolding learning: Principles for effective teaching and the design of classroom resources. In M. Abend (Ed.), *Effective teaching and learning: Perspectives, strategies and implementation* (pp. 1–43). Nova Science Publishers.
- Taber, K. S. (2020). Mediated learning leading development – The social development theory of lev Vygotsky. In B. Akpan & T. Kennedy (Eds.), *Science education in theory and practice: An introductory guide to learning theory* (pp. 277–291). Springer.
- Taber, K. S., & Brock, R. (2018). A study to explore the potential of designing teaching activities to scaffold learning: Understanding circular motion. In M. Abend (Ed.), *Effective teaching and learning: Perspectives, strategies and implementation* (pp. 45–85). Nova Science Publishers.
- Taber, K. S., & Li, X. (2021). The vicarious and the virtual: A Vygotskian perspective on digital learning resources as tools for scaffolding conceptual development. In A. M. Columbus (Ed.), *Advances in psychology research* (Vol. 143). Nova Science Publishers.
- Thorpe, M. (2002). From independent learning to collaborative learning. In M. R. Lea & K. Nicoll (Eds.), *Distributed learning* (pp. 131–151). Routledge.
- Tsai, M. J., & Tsai, C. C. (2003). Information searching strategies in web-based science learning: The role of internet self-efficacy. *Innovations in Education and Teaching International*, 40(1), 43–50. <https://doi.org/10.1080/1355800032000038822>
- Tu, Y. C., Tempero, E., & Thomborson, C. (2016). An experiment on the impact of transparency on the effectiveness of requirements documents. *Empirical Software Engineering*, 21, 1035–1066. <https://doi.org/10.1007/s10664-015-9374-8>
- Tyson, M. M., & Sauers, N. J. (2021). School leaders' adoption and implementation of artificial intelligence. *Journal of Educational Administration*, 59(3), 271–285. <https://doi.org/10.1108/JEA-10-2020-0221>
- UNESCO. (2022). *K-12 AI curricula. A mapping of government-endorsed AI curricula*. <https://unesdoc.unesco.org/ark:/48223/pf0000380602>
- UNESCO. (2023). *Ethics of artificial intelligence*. <https://www.unesco.org/en/artificial-intelligence/recommendation-ethics>.
- Uz-Bilgin, C., & Thompson, M. (2022). Processing presence: How users develop spatial presence through an immersive virtual reality game. *Virtual Reality*, 26(2), 649–658. <https://link.springer.com/article/10.1007/s10055-021-00528-z>
- van Lier, L. (2008). Agency in the classroom. In J. P. Lantolf & M. E. Poehner (Eds.), *Sociocultural theory and the teaching of second languages* (pp. 163–186). Equinox.
- Verenikina, I. (2010). *Vygotsky in twenty-first-century research*. In Proceedings of world conference on educational multimedia, Hypermedia and Telecommunications. AACE. <https://www.learnedlib.org/primary/p/35264/>

- Vygotsky, L. S. (1978). In M. Cole, V. Jolm-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in society: The development of higher psychological processes*. Harvard University Press. <https://doi.org/10.2307/j.ctvjf9vz4>
- Wong, W. H., & Kindarji, V. (2023, March 11). *Digital literacy will be key in a world transformed by AI*. The Global and Mail. <https://www.theglobeandmail.com/opinion/article-digital-literacy-will-be-key-in-a-world-transformed-by-ai/>.
- Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem-solving. *The Journal of Child Psychology and Psychiatry*, 17(2), 89–100. <https://doi.org/10.1111/j.1469-7610.1976.tb00381.x>
- Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 62, 41–49. <https://doi.org/10.1016/j.compedu.2012.10.024>
- Zion, M., Cohen, S., & Amir, R. (2007). The spectrum of dynamic inquiry teaching practices. *Research in Science Education*, 37(4), 423–447. <https://doi.org/10.1007/s11165-006-9034-5>

Chapter 11

ICT Use in Blog Design: A Study of Pre-service Preschool Teachers During Pandemic



Ali İbrahim Can Gözüml  and Ümit Ünsal Kaya 

Introduction

Incorporating information and communication technologies (ICT) has notably reshaped the educational sphere (Jimoyiannis & Komis, 2007; Roussinos & Jimoyiannis, 2019). The benefits of ICT in teaching and learning are recognized. Nevertheless, the success of its integration rests on teachers' expertise across various domains such as subject content, understanding student cognition, and technological proficiency (Angeli & Valanides, 2009; Gur & Karamete, 2015; Koehler & Mishra, 2009; Koehler et al., 2013). The COVID-19 pandemic heightened the importance of these skills, driving educators globally to transition to online platforms.

Pre-service teachers assume increased significance in this milieu, especially those preparing for preschool roles. Research highlights that teacher beliefs, digital acumen, and perceived barriers to technology impact digital technology incorporation in early education (Blackwell et al., 2013; Masoumi, 2015; Nikolopoulou &

This study is an extension of previous research orally presented by Ali İbrahim Can Gözüml at the 8th International Symposium on Instructional Technology and Teacher Education (Uluslararası Öğretim Teknolojileri ve Öğretmen Eğitimi Sempozyumu), held from November 17–19, 2021. The presentation, “Blog Design In The Scope Of Community Service In The Pandemic Process: An Investigation Of Pre-service Preschool Teachers' Use Of Information And Communication Technologies,” was the foundation for this in-depth exploration.

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Gialamas, 2015). Teacher education programmes are pinpointed as vital in equipping teachers with digital capabilities.

In response to the pandemic, the Turkish Higher Education Council (YÖK) advocated online education to sustain educational endeavours, though this transition posed unique challenges for teacher training. A silver lining emerged as projects under the community services course were digitized. This study delves into this shift, scrutinizing ICT use by 48 pre-service teachers in their blog designs. These insights will shed light on their digital navigation for educational ends and guide enhancements in teacher training programmes to fortify digital skills (Cuban, 2001; Farmer, 2016).

Therefore, harnessing ICT optimally in teacher training is anticipated to boost pre-service teachers' digital and professional growth. This progress promises benefits for the educators' eventual careers and the digital development of children (Cuban, 2001; Farmer, 2016). Consequently, this study amplifies the discourse on ICT's pivotal role in teacher education and its potential influence on early childhood education's trajectory.

ICT in Early Childhood Education

Information and communication technologies (ICT) have profoundly impacted various sectors, especially education. Its importance in early childhood education is well established (Peeraer & Van Petegem, 2011). As digitalization becomes pervasive, introducing children to ICT from a tender age becomes crucial, supported by extensive research (Plowman et al., 2008; Yelland, 2007; Judge et al., 2006; Blackwell et al., 2014).

Global educational reforms prioritize ICT's inclusion, viewing it as essential for future societal involvement and employability (Blackwell et al., 2014; Siddiq & Scherer, 2016). Numerous studies have explored ICT's role in enhancing children's developmental outcomes, creative thinking, and social interactions (Bolstad, 2004; Dong et al., 2020; Hu & Yelland, 2017; Nikolopoulou & Gialamas, 2015; Masoumi, 2015; Kim, 2020; Gayatri, 2020). Successful ICT integration, however, requires aligning technology with pedagogical practices and prioritizing educators' professional development.

Empirical studies highlight ICT's potential to boost children's language, communication, and creativity (Nikolopoulou & Gialamas, 2015; Ploughman et al., 2012; Clements & Sarama, 2003; McKenney & Voogt, 2012). Additionally, it can foster mathematical reasoning and enhance social collaboration (Hatzigianni & Margetts, 2012; Howard et al., 2012; Jack & Higgins, 2019; Kalas, 2010). While ICT holds transformative potential, its successful implementation relies heavily on teachers' proficiency (Yelland, 2007; Tondeur et al., 2017).

Teachers' ICT competency is paramount for quality digital-based learning experiences (Yelland, 2007; Tondeur et al., 2017). Additionally, parents and educators must ensure the appropriateness of the digital content children access (Gözümlü et al., 2023; Gözümlü, 2022; Gözümlü & Kandır, 2021; Papadakis & Kalogiannakis, 2020).

Despite global efforts, significant digital divides persist in education, highlighted during the 2020 COVID-19 pandemic (Judge et al., 2006; Blackwell et al., 2014; UNESCO, 2022). UNESCO (2022) urges policymakers to ensure inclusivity, equity, and gender equality in ICT integrations. Implementing these standards demands continuous teacher training and updating policies to keep pace with ICT advancements (Gur & Karamete, 2015).

Türkiye's educators exhibit a positive attitude towards ICT, echoing global sentiments (Konca et al., 2016; Plowman et al., 2012; Yelland, 2007). However, challenges like inadequate resources hinder its practical application (Kabadaşı, 2006; Simsar & Kadim, 2017). This reflects the broader global scenario, where ICT use often remains non-systematic (Asorey & Gil, 2009; Fernández & Bermejo, 2012; Fernández & Torres, 2015; Rambousek et al., 2016). Strengthening initial and ongoing teacher training can bridge this gap (Cabezas et al., 2014; Casillas & Cabezas, 2014; Rambousek et al., 2016). Continual research is vital to adapt to ICT's rapidly evolving nature and meet learners' changing needs.

Embracing Digital Competencies: The Landscape of ICT Integration in Pre-service Preschool Teacher Education

As society advances with information and communication technology (ICT), educators must stay abreast of this progression. Preschool teachers have been highlighted as crucial conduits of ICT integration, shaping early childhood digital literacy perceptions and attitudes (Kalogiannakis & Papadakis, 2017; Samuelsson, 2019; Siraj-Blatchford & Siraj-Blatchford, 2003; Plowman et al., 2008).

Current literature reveals that teacher training often needs to pay more attention to instilling digital competencies in pre-service teachers, resulting in their perceived unpreparedness for ICT integration (Tiede, 2020; Tiede et al., 2015; Tondeur et al., 2017). Addressing this requires curricula grounded in empirical best practices and the principles of ISTE, TPACK, and DigCompEdu frameworks.

Teachers' attitudes are central to in-class ICT integration (Knezek & Christensen, 2016; Petko, 2012; Seufert et al., 2021; Bas et al., 2016). While many pre-service teachers display a cheerful disposition towards ICT (Gretter & Yadav, 2018), discrepancies arise when their educational training inadequately prepares them for practical technology integration (Brevik et al., 2019; Brown et al., 2016; Tondeur et al., 2012; Gudmundsdottir & Hatlevik, 2018; Enochsson, 2010). This underscores the need for hands-on digital competency training.

Considering the varied proficiency levels and attitudes towards ICT integration across different contexts (Tondeur et al., 2012), it is evident that despite strong technical skills, many pre-service teachers lack the confidence or pedagogical knowledge for ICT assimilation (Tondeur et al., 2018; Heitink et al., 2017). Thus, a nuanced, context-sensitive approach is required in training programmes.

Frameworks like the ISTE have outlined clear standards for technology-enhanced teaching (ISTE, 2017). The TPACK framework provides insight into the interrelation between technology, pedagogy, and content knowledge, enhancing our understanding

of effective technology integration (Mishra & Koehler, 2006; Harris et al., 2009; Papadakis et al., 2018). Concurrently, the European Framework for the Digital Competence of Educators (DigCompEdu) presents a detailed model for pre-service teacher development (Redecker & Punie, 2017; Krumsvik, 2011, 2014; Farjon et al., 2019; Bocconi & Panesi, 2018).

Recent research by Papadakis et al. (2022), Kalogiannakis and Papadakis (2019), and Gözüüm et al. (2022, 2023) underscores the importance of embedding these standards in teacher education programmes to equip preschool teachers for digital-era classrooms.

Incorporating ISTE, TPACK, and DigCompEdu into curricula is essential, given the empirical support and contemporary classroom demands. Nevertheless, understanding the diverse experiences, attitudes, and sociocultural influences is equally paramount. A holistic approach, which not only imbibes these frameworks but also comprehends these varied dimensions, will cultivate educators aptly equipped for the digital nuances of early childhood education.

The Role and Evolution of the Compulsory Community Services Course in Preschool Education Programmes in Türkiye: Navigating the Intersection of ICT Amidst the Pandemic

The Compulsory Community Services Course, central to pre-service preschool education in Türkiye since its 2006 introduction by the Turkish Higher Education Council (YÖK), aims to equip students to address societal challenges. The course promotes societal sensitivity and project-based solutions to community issues (Seferoğlu, 2004).

Underpinned by contemporary educational demands, the course's inclusion in the curriculum enhanced pre-service teachers' competencies in societal problem-solving. The curriculum highlights scientific methodologies and emphasizes project design, social responsibility, and the fundamental principles underlying community service applications (Kocadere & Seferoğlu, 2013).

However, the COVID-19 pandemic disrupted this course, particularly its practical components. In response, instructors innovatively utilized ICT to maintain course delivery, while the rise of Web 2.0 tools, such as blogs, reshaped interactions between pre-service teachers, families, and children, further accelerated by the pandemic's demand for remote interactions.

Before the pandemic, community service projects emphasized direct interactions, serving as crucial experiential platforms for pre-service teachers. The shift to online due to the pandemic required adapting to digital tools and reinventing the community service framework. As pre-service teachers enhanced their ICT skills, the importance of integrating these tools pedagogically emerged (Tondeur et al., 2018). This shift demanded understanding how to create meaningful digital interactions tailored to community needs.

This digital transition represented an evolution in community service education, pushing it towards a more digitally integrated realm. However, challenges arose, with many pre-service teachers grappling with the rapid digital integration and certain course content proving challenging to adapt online.

In summary, the compulsory community service course's adaptation during the pandemic underscored the importance of ICT in shaping modern preschool teacher education in Türkiye. Despite challenges, during this period, we offered valuable insights into the evolving digital landscape of teacher education, emphasizing the need for both technological and pedagogical proficiency in future curricula.

In response to the escalating importance of ICT in education, this study delves into using ICT tools by pre-service preschool teachers in Türkiye, explicitly focusing on blog design for community service amidst the pandemic. Through a three-stage process—content selection, digital transformation, and dissemination via platforms like Facebook, Instagram, and YouTube—the research evaluates ICT competencies during the blog design task within the community service course framework. Carried out over two academic years (2019–2020 and 2020–2021) involving 48 participants, this study provides valuable insights for enhancing strategies and pedagogical approaches for integrating ICT into teacher education.

Methodology

This study follows a phenomenological research design, aiming to understand the phenomenon of preschool teachers' ICT usage—a well-acknowledged topic yet inadequately understood. Phenomenological research examines manifestations of life experiences, such as perceptions, situations, and events (Annells, 2006; Creswell, 2013; Yıldırım & Şimşek, 2016). Specifically, this research evaluates blogs to grasp pre-service teachers' experiences and perceptions regarding ICT. The intent is to deeply understand pre-service teachers' views and designs related to ICT without aiming for generalization (Merriam, 2013).

Study Group

The sample includes 48 pre-service preschool teachers from a state university in Eastern Anatolia, Türkiye, distributed across two academic years: 2019–2020 and 2020–2021. These participants, who had completed a computer literacy course in their first undergraduate year, were involved in pandemic-era projects for a community service course and voluntarily joined this research. Participants were chosen through purposive sampling (Neuman, 2014), emphasizing their blog use as a metric for ICT engagement. All participants shared a common sentiment of ICT inadequacy before their community service course, revealed in an online meeting. Given the pressing need for ICT due to pandemic restrictions, focus group discussions were structured around homogeneous groups regarding gender, class, seniority, and

Table 11.1 Demographic and educational characteristics of the pre-service teachers participating in the study

Variable	n	%
Gender		
Female	36	75
Male	12	25
Seniority		
Second year	48	100
Taken computer literacy course		
Yes	48	100
No	–	–

views on ICT (Creswell, 2013; Flick, 2014). Table 11.1 delineates participants' demographic details.

Based on the personal information of the participants in Table 11.1, 75% are female ($n = 36$), while 25% are male ($n = 12$). The pre-service teachers participating in the study are at the undergraduate level in their second year. All of the pre-service teachers have taken a computer literacy course.

Data Collection

Data was sourced from online focus group discussions and blogs curated by participants over two academic years (2019–2020 and 2020–2021) in the context of a community service applications course. This employed online focus group discussions and document analysis of the blogs as primary collection techniques.

Pre-service preschool teachers discussed ICT projects planned over 9 weeks in these online focus groups, held via Microsoft Teams. The researcher moderated these discussions, prompting participants on their ICT application within their community service projects. This setup encouraged participants to engage deeply, sharing insights and gaining varying perspectives. These discussions were structured with participants being grouped into subgroups, scheduled discussions during mid-week afternoons, using Microsoft Teams as the platform, and following a predetermined plan focusing on ICT usage insights. Pertinent questions included inquiries into the benefits of ICT in preschool classrooms and its integration into blogs. These online sessions, approximately 45 min each, were recorded with participant consent.

Blogs served as digital platforms where pre-service preschool teachers individually shared content related to the pandemic, ranging from articles and videos to infographics. Updated weekly, these blogs were aimed at informing the community and receiving feedback. The creation and management of these blogs followed a systematic process: selection of the blogger platform, blog initiation, inviting participation, content determination based on online discussions, post publishing, and encouraging interactive discussions. These blogs enhanced the teachers' digital competencies and fostered an interactive community learning and feedback space.

Validity and Reliability

This study employed a qualitative research approach, using criteria tailored to ensure the validity and reliability of data from online focus group discussions and document analysis.

To preserve authenticity, a platform was provided for pre-service preschool teachers to share their ICT experiences without the influence of grading openly. To ascertain the relevance of the questions posed during the online discussions, experts assessed them, including two specialists in preschool technology education, one in computer and instructional tech, and two linguists. Feedback confirmed the questions' appropriateness.

The role of the moderator in such discussions can shape responses. To avoid this, our moderator remained impartial, allowing for candid input. Discussions were recorded in video format for rigorous analysis and to bolster reliability.

Regarding document analysis, Scott (2014) outlines four criteria: authenticity, accuracy, originality, and contemporaneity. The blogs created by the pre-service teachers during the pandemic were analysed as scholarly documents. Sourced from official university department websites, these blogs were treated as both contemporary and genuine. The blogs, reflecting the individual insights and research of the teachers, were deemed original and free from imitation. A content analysis of these blogs revealed three overarching themes: information, communication, and technology.

Data Analysis

Data from online focus group discussions and document analysis underwent a structured analytical process. Video recordings from the online discussions offered a rich dataset by capturing teacher candidates' facial cues, intonations, and interactions. These recordings were transcribed into text and then analysed using thematic coding. Codes centred on specific themes or salient ideas such as "ICT's influence on learning", "ICT tool challenges", "ICT examples in content", and "ICT's effect on teaching". These codes enabled the isolation of relevant sections within the transcripts. By analyzing these coded sections, key themes, trends, and insights emerged, deepening the understanding of candidates' perspectives on ICT. Direct quotes from participants, coded for identification (e.g. "MTC1" for a male teacher or "FTC2" for a female teacher), were highlighted to represent genuine reflections on ICT usage.

For the blogs, a descriptive analysis was employed. Throughout this process, blogs were comprehensively reviewed, and content related to the dimensions of information, communication, and technology was categorized. Direct quotes for these categories came as excerpts or images from the blogs. After categorizing, coded data were compiled, related to existing literature, and synthesized. The unified results from the blog and online discussion analyses are presented in Table 11.2.

Table 11.2 Integration of themes and categories derived from blog and online discussion analyses

Blog	Online discussion
Theme	Category
Information	Access to information using ICT
	Planning content according to age levels in ICT usage
	Ease of access to scientific knowledge in ICT usage
Communication	The impact of ICT on learning experiences
	The influence of ICT on teaching experiences
	ICT facilitates communication with parents
	Communication challenges directed at children using ICT
Technology	Challenges in using ICT tools
	Examples of ICT usage in terms of learning content
	Technological proficiency in ICT usage

Findings





Before presenting the detailed findings, it is essential to observe specific examples that elucidate how pre-service teachers integrated various themes into their blogs. Table 11.3 offers illustrative excerpts from these blogs, emphasizing the theme of information dissemination.

According to Table 11.3, pre-service teachers access information using ICT for information retrieval. They have indicated that they pay attention to preparing activities according to children's ages when conveying the obtained information to children. They also emphasize the sources of information provided to children and parents and ensure its scientific content. In this context, the findings related to the information theme obtained with direct quotations from pre-service teachers are as follows:

Under the "Information" theme, pre-service teachers' views on the "Accessing information using ICT" category are:

- Thanks to Web 2.0 tools, pre-service teachers can access information faster and more easily. ICT can provide broader access, especially with online resources and educational materials. (MTC1).
- Accessing information using ICT provides pre-service teachers with access to various learning resources. Teachers can access information using various media types (text, video, audio). (FTC3).
- Web 2.0 tools provide pre-service teachers access to numerous online resources to support their learning. Pre-service teachers can shape their learning journeys about ICT using these tools. (FTC7).

Table 11.3 Examples of the information theme from pre-service teachers' blogs

	Prepared by the teacher candidate, a presentation on COVID-19 symptoms and prevention methods for children
	Prepared by the teacher candidate, a video on precautions for children's technology use at home
	Prepared by the teacher candidate, a video related to children's nutrition
	Prepared by the teacher candidate, a practical video on how education should be at home during the COVID-19 process

- Regarding information access, Web 2.0 tools provide pre-service teachers more independence and freedom. We can quickly access the information we want, making learning more enjoyable. (MTC3).
- Accessing information using ICT equips pre-service teachers with the skill to connect with online resources and use them. (FTC9).

These student views emphasize the importance of Web 2.0 tools in accessing information and how these tools can enrich learning. Accessing ICT information can make students' learning experiences more interactive and diversified.

Under the "Information" theme, pre-service teachers' views on the "Planning content according to age levels in ICT usage" category are:

- When content is planned according to age levels, it ensures better understanding and assimilation of the content by children. This approach is essential for preschool children. (FTC10).
- ICT usage is a great opportunity to adapt content to different age groups. Providing content suitable for children’s needs and levels can make learning more effective. (FTC14).
- The advantage of planning content according to age levels is that teachers can offer students more appropriate and engaging materials. This can make the learning experience more satisfying. (FTC19).
- Age-appropriate content planning can make learning more enjoyable. Especially for children, learning materials must be engaging and fun. (FTC20).
- When content is organized according to age levels, children become more motivated and learn more deeply. This can help teachers achieve better results. (MTC9).
- ICT provides teachers with more flexibility in finding and implementing age-specific content. This can offer children a better learning experience. (MTC10).

These teacher-candidate views emphasize the importance of planning content according to age levels. Using ICT offers the opportunity to present students with more appropriate, engaging, and effective learning materials, enhancing children’s learning experiences.

Under the “Information” theme, pre-service teachers’ views on the “Researching scientific knowledge in ICT usage” category are:

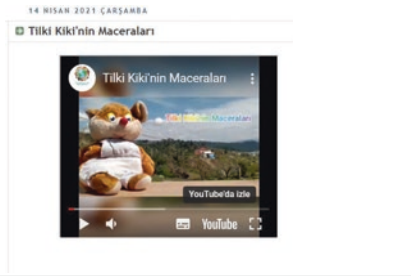
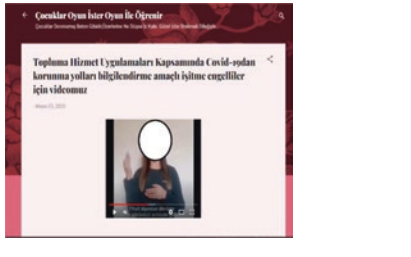

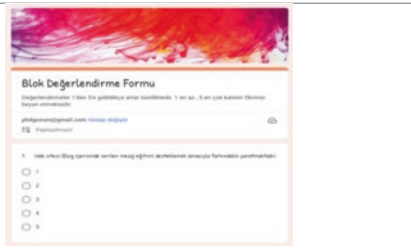
- Accessing scientific information using ICT allows children to easily access current and accurate sources. This greatly facilitates the research and learning processes. (FTC18).
- ICT usage provides quick and easy access to scientific journals and research articles. This facilitates pre-service teachers in finding reliable sources to support community service projects. (FTC32).
- Accessing scientific information through ICT tools like Web 2.0 enriches children’s learning experiences. (FTC27).
- Thanks to ICT usage, they can access scientific information faster and more effectively. This facilitates and accelerates the digital content processes I will prepare for children. (MTC9).

These teacher candidate views emphasize the importance of accessing scientific information through ICT. This can help students have better learning experiences and access information more consciously (Table 11.4).

Under the “Communication” theme, pre-service teachers’ views on the “Impact of ICT on learning experiences” category are:

- The impact of ICT on learning experiences is significant. ICT tools offer pre-service teachers a more interactive and engaging learning environment. (FTC24).
- ICT helps personalize learning experiences. It creates an environment where everyone can learn at their own pace and style. (FTC21).
- ICT tools encourage collaboration among pre-service teachers. This provides an ideal platform for group projects and discussions. (FTC20).
- ICT makes learning materials more engaging. It offers visual and auditory learning opportunities for children. (FTC19).
- It provides easy access to online resources and educational materials for children. This enriches the learning experiences. (FTC8).
- ICT diversifies students’ learning experiences. It can make activities that might be boring more engaging. (MTC4).

Table 11.4 Examples of the communication theme from pre-service teachers’ blogs

	<p>A video work prepared by the teacher candidate using puppets, focusing on learning experiences for children during the COVID-19 period</p>
	<p>A video prepared by pre-service teachers using sign language aimed at teaching deaf and hard-of-hearing children about protection methods from COVID-19. The video preparation process involved collaboration among 14 pre-service teachers</p>
	<p>A virtual museum tour prepared by the teacher candidate for children and parents. The teacher candidate adds their image to the bottom left corner of the three-dimensional images of the museums and describes the museum. After the video, a communication channel is opened to ask questions and get children’s opinions</p>
	<p>Parents fill out a blog evaluation form prepared by the teacher candidate. Through the form, parents comment on their children’s development, and communication is established via email addresses</p>

These teacher candidate views show that ICT positively influences learning experiences, providing a more interactive, personalized, and varied learning environment. ICT aids students in learning more actively and participatively.

Under the “Communication” theme, pre-service teachers’ views on the “Impact of ICT on teaching experiences” category are:

- ICT makes teaching experiences more interactive. It helps us better connect with activities during the teaching process and makes learning materials more engaging. (FTC23).
- ICT tools help make learning materials easier to understand, especially for visual learning. (FTC24).
- ICT makes teaching experiences more accessible. It offers the opportunity to support learning by providing more resources and materials to children. (FTC25).
- As a preschool teacher candidate, I believe ICT tools help me communicate better with children. Digital platforms assist in our interaction with our students. (FTC12).
- ICT offers more originality and functionality when planning activities. Touch devices allow children to manage their learning processes more independently. (FTC14).
- ICT tools help make activities more fun and engaging. Students participate more. (MTC6).
- ICT offers visual and auditory elements to help concretize activities and capture children's interest. This can be a better learning experience for children. (MTC9).

These teacher candidate views show that ICT enhances teaching experiences, helping pre-service teachers create better materials, increasing student-teacher interaction, and offering children more freedom.

Under the "Communication" theme, pre-service teachers' views on the "ICT facilitating communication with parents" category are:





- ICT allows us to communicate more easily with parents. Through digital platforms like blogs, we can quickly relay current information to our parents. (FTC21).
- ICT tools make it easier for parents to closely monitor their children's development in front of screens. Sharing children's work with parents through digital outputs is great. (FTC31).
- It allows parents to participate more in children's lesson materials and learning processes. This provides more support for children's development. (FTC9).
- Thanks to digital communication tools, staying in regular contact with parents is easier. We can quickly answer their questions. (FTC13).
- It helps parents monitor their children's learning progress. Communication becomes more transparent with digital reports and current development templates. (MTC11).
- Communicating more with parents can enhance children's development. As communication becomes easier, parents can provide more support. (MTC8).

These student views show that ICT facilitates communication with parents and makes communication between school and home more transparent. This can increase students' academic achievements and encourage more parent participation.

Under the "Communication" theme, pre-service teachers' views on the "Communication challenges with children in ICT" category are:

- Care should be taken when communicating with children using ICT. We should pay special attention to anonymity, security, and privacy issues. (FTC18).
- When using ICT tools to communicate with children, age-appropriate content and language should be used. Also, online safety for children should be a priority. (FTC13).
- ICT can help us overcome language barriers in communication with children. We can increase children's participation by offering materials in different languages. (FTC6).
- The challenge of communicating with children using ICT stems from the rapid technological changes. As teachers, we must always stay updated. (FTC14).
- When communicating effectively with children, we should consider their digital skills and interests. We can use digital tools to capture their interest. (FTC12).

Table 11.5 Examples of the technology theme from pre-service teachers' blogs

	<p>Pre-service teachers have undertaken the necessary work to set up a blog. This includes obtaining an email address, setting up the blog, and showcasing a blog example that utilizes various web 2.0 tools post-setup</p>
	<p>Examples of pre-service teachers that require technological proficiency are preparing different visuals, adding sound to visuals, and merging visuals into a video</p>
	<p>A logo designed by the teacher candidate for blog promotion. Due to different software versions and their inherent differences, pre-service teachers prepared various design samples during the logo design process</p>
	<p>An example by a teacher candidate in an audio story application highlights the relationship that emerges between pedagogical content knowledge and technological proficiency</p>

- Encouraging parent participation when communicating with children using ICT is important. Parents should monitor children’s online activities and provide guidance. (MTC2).
- The biggest challenge in communicating with children is online dangers. Education and supervision are required against these dangers. (MTC5).

These teacher candidate views emphasize that while ICT offers opportunities for communication with children, attention must be paid to children’s safety, privacy, and age-appropriate content. They also highlight the importance of teachers approaching technology appropriately and staying updated (Table 11.5).

Under the “Technology” theme, pre-service teachers’ views on the “Challenges of using ICT tools” category are:

- For some pre-service teachers, using technology can be challenging, so extra assistance and guidance should be provided. (FTC35).
- Internet connectivity and device access can vary based on the home conditions of pre-service teachers, leading to disparities. (FTC32).
- Effectively using ICT tools relates to the skills and experiences of pre-service teachers. Some may need more training and practice. (FTC13).
- Security concerns can bring additional responsibilities, especially ensuring the safety of children on online platforms. (FTC14).
- Developing and updating technology-based learning materials can be time-consuming. Pre-service teachers must consider the time they can allocate to this process. (MTC12).
- ICT tools are frequently updated and change, which may require pre-service teachers to stay updated consistently. (MTC7).

These views from pre-service teachers indicate that using ICT tools can present challenges, especially related to student disparities, teacher skills, and security concerns. They also highlight the time and resources teachers require to develop and update technology-based learning materials.

Under the “Technology” theme, pre-service teachers’ views on the “Examples of using ICT in terms of learning content” category are:

- ICT tools like online games and interactive simulations can capture children’s attention and make learning fun. (MTC7).
- Virtual field trips can offer children real-world experiences, such as visits to museums or historical sites. (FTC17).
- Tools for video creation or digital storytelling can be used to create interactive lesson materials. (MTC4).
- Online discussion forums can allow parents to explore different perspectives and develop critical thinking skills. (MTC9).
- ICT can assist pre-service teachers in creating personalized learning materials and better addressing children’s individual needs. (FTC8).
- It is important to teach children and parents how to use online resources safely and effectively. Information access skills should be developed. (FTC6).

These views from pre-service teachers show that ICT offers a wide range of methods to enrich and personalize learning content. They provide examples like games, virtual field trips, and interactive materials to make learning more effective and enjoyable. They also emphasize ICT tools to help students collaborate, think critically, and access information.

Under the “Technology” theme, pre-service teachers’ views on the “Technological proficiency in ICT usage” category are:

- I am not proficient in technology but open to learning. With more training and guidance, I can use ICT more effectively. (FTC13).
- I am proficient in technology and can comfortably use Web 2.0 tools. Therefore, I do not face challenges integrating these tools effectively into lessons. (FTC15).
- I have basic technology knowledge but did not feel competent using more advanced ICT tools. I believe I have improved with practice. (MTC4).
- I have some experience with computers and digital tools, but I want to explore and learn more about ICT tools. (MTC12).
- I had a significant bias against technology, and I wondered what I would do at the beginning of this course. Now, I want to improve my ICT skills. (FTC27).

- I use technology only for daily use, but I realized I need to use it more for integration in education. Using ICT is not as hard as I thought... (MTC1).
- My proficiency in ICT varies. I can comfortably use some tools but need to learn more about others. I have realized in this course that I can improve. (FTC2).
- I did not have much experience with technology, but through these lessons, as I learned and gained new skills, I believed that technology should be in education. (FTC3).

The views of pre-service teachers on technological proficiency vary. While some are proficient in ICT, others need more training and practice. However, most students emphasize that these courses are a significant opportunity to enhance their technological skills.

Discussion and Conclusion

The integration of information and communication technologies (ICT) in early childhood education, especially within the context of Türkiye, is a testament to the global shift towards digital pedagogy. As we delve into the study's findings and the insights shared, it becomes evident that the role of ICT in pre-service teacher education is not just transformative but also pivotal in shaping the future of education.

Integrating information and communication technologies (ICT) in education, particularly pre-service teacher training, has become a pivotal force driving pedagogical evolution. The findings from the study presented offer a comprehensive exploration of this transformative role, shedding light on the multifaceted ways in which ICT is reshaping instructional methodologies, content dissemination, and the broader paradigms of educational communication.

Pre-service teachers' increasing adoption and integration of Web 2.0 tools are at the heart of this transformation. As delineated in the study, these digital tools are not merely supplementary aids but have become central to the pedagogical processes. This observation is congruent with the findings of Jimoyiannis and Komis (2007) and Roussinos and Jimoyiannis (2019), who have previously highlighted the profound impact of ICT on teaching methodologies and student engagement. Furthermore, the emphasis on Web 2.0 tools, as evidenced in the study, underscores a shift towards a more interactive, collaborative, and student-centred approach to learning. This shift aligns with the broader academic discourse advocating cultivating digital literacy skills as an essential competency for the twenty-first century (Plowman et al., 2008; Gur & Karamete, 2015).

Another salient aspect of the study's findings is the innovative deployment of ICT tools in creating and designing educational blogs by pre-service teachers. As the study suggests, these digital platforms serve as dynamic spaces for knowledge dissemination, interaction, and collaborative learning. The emphasis on blog designs, enriched with multimedia elements and interactive features, mirrors the findings of Blackwell et al. (2013) and Masoumi (2015). These studies have previously highlighted the potential of digital platforms in fostering a more connected

and engaged learning community. In the context of the study presented, these blogs bridge communication gaps and serve as repositories of knowledge, facilitating asynchronous learning and fostering a sense of community among learners.

Furthermore, the study's emphasis on the innovative use of ICT tools, particularly in the design and dissemination of content, resonates with the observations made by Angeli and Valanides (2009). Their research underscores the potential of ICT in enhancing the quality of content delivery, making it more accessible, engaging, and tailored to the diverse needs of learners. The study's findings, in this regard, offer a testament to the myriad ways in which pre-service teachers harness the power of ICT to create content that is not only pedagogically sound but also interactive and engaging.

While promising, integrating information and communication technologies (ICT) into the educational landscape is complex. The study in question offers a nuanced exploration of these intricacies, mainly focusing on the varied technological proficiencies observed among pre-service teachers and the challenges they face in effectively integrating ICT into their pedagogical practices.

The observed spectrum of technological proficiency among pre-service teachers is central to this discussion. As the study delineates, this spectrum is vast, encompassing those adept at harnessing advanced ICT tools and those in the nascent stages of their digital exploration. This observation is congruent with the findings of Koehler and Mishra (2009) and Koehler et al. (2013), who have previously highlighted the varied technological competencies among educators. Their research underscores the imperative for continuous professional development, emphasizing that while technological proficiency is crucial, it must be complemented by pedagogical knowledge to ensure effective ICT integration (Gözümlü & Demir, 2021).

However, as the study suggests, the journey towards effective ICT integration is fraught with challenges. One of the primary challenges highlighted is the disparities in access to ICT tools. This disparity, often rooted in socio-economic factors, can lead to an uneven playing field, where some pre-service teachers have a distinct advantage due to their access to better technological resources. This observation resonates with the findings of Tiede (2020) and Tiede et al. (2015), who have emphasized the need for equitable access to ICT resources to ensure a uniform level of technological proficiency among educators.

Furthermore, the study brings the challenges associated with online security. As pre-service teachers venture into the digital realm, they face many security concerns, ranging from data privacy to online safety, especially when interacting with younger learners. These concerns are consistent with the broader challenges highlighted in the literature, with researchers like Tondour et al. (2017) emphasizing the need for robust digital ethics and safety protocols in teacher training curricula.

Another salient challenge highlighted by the study is the rapid pace of technological advancements. The ever-evolving nature of technology necessitates that pre-service teachers remain agile, continuously updating their skills and knowledge to stay abreast of the latest developments. This observation aligns with the broader academic discourse, which underscores the imperative for continuous professional development in the face of rapid technological advancements.

While the potential of ICT in reshaping the educational landscape is undeniable, the challenges associated with its integration cannot be overlooked. The study offers a comprehensive exploration of these challenges, emphasizing the need for a multi-faceted approach to address them. This approach should encompass continuous professional development, equitable resource access, robust digital safety protocols, and harmonizing technological proficiency with pedagogical knowledge. Only then can we harness the true potential of ICT in shaping the educators of tomorrow.

Integrating information and communication technologies (ICT) into educational practices has been the subject of extensive academic inquiry over the past few decades. The study in question offers valuable insights into specific facets of this integration, particularly emphasizing the importance of age-appropriate content planning and the significance of accessing scientific information through ICT. A comparative analysis with previous research provides a richer understanding of these findings, situating them within the broader academic discourse on ICT in education.

A salient theme emerging from the study is the emphasis on age-appropriate content planning. This focus is not isolated but finds resonance in the broader academic literature. Tondeur et al. (2018) highlighted the criticality of tailoring educational content to align with learners' developmental stages and cognitive capacities. Their research underscores that age-appropriate content facilitates better comprehension and ensures learners remain engaged and motivated. Similarly, Heitink et al. (2017) have emphasized the importance of designing content that caters to learners' unique needs and characteristics, arguing that such an approach is instrumental in fostering deeper learning and ensuring meaningful educational experiences.

Furthermore, the study's findings on the significance of accessing scientific information through ICT offer another avenue for comparative analysis. The emphasis on evidence-based practices in education, as highlighted in the study, is a recurring theme in academic literature. Redecker and Punie (2017) has extensively discussed the importance of grounding educational practices in empirical evidence, arguing that such an approach ensures the efficacy and relevance of pedagogical interventions. This sentiment is further echoed by Krumsvik (2011, 2014), who posits that accessing scientific information through ICT tools can significantly enhance the quality of educational content. By leveraging evidence-based practices, educators can ensure that their teaching methodologies and content are current and rooted in robust scientific research.

The study's findings significantly impact future teacher training programmes and ICT integration in education.

- *Holistic Teacher Training*: Teacher training programmes should be revised to incorporate a more robust focus on ICT integration. This includes technical and pedagogical training to ensure pre-service teachers can effectively integrate technology into their teaching practices (Gretter & Yadav, 2018).
- *Safety and Ethics*: While offering boundless opportunities, the digital realm also presents challenges. The concerns voiced by pre-service teachers about online

safety, especially when interacting with children, accentuate the pressing need for robust digital ethics and safety protocols in teacher training curricula.

- *Parental Engagement*: As highlighted in the findings, ICT is a potent tool for amplifying teacher-parent communication. Training programmes should prioritize strategies that leverage digital platforms to foster transparent, collaborative, and enriching relationships with parents.
- *Continuous Professional Development*: With technology evolving quickly, educational institutions must prioritize continuous professional development programmes. These should focus on technological proficiency and pedagogical adaptability, ensuring educators remain at the forefront of educational innovation.
- *Collaborative Learning*: A community of practice where pre-service teachers collaboratively share their expertise and challenges related to ICT can be instrumental in enhancing collective proficiency. Such collaborative endeavours can foster a rich learning environment, promoting shared growth.

In conclusion, as we navigate the intricate maze of the educational landscape, which is in constant flux due to technological advancements, it becomes abundantly clear that teacher training programmes must evolve in tandem. The onus is on ensuring that the educators of tomorrow are adeptly equipped to harness the boundless potential of ICT, laying the foundation for meaningful, impactful, and transformative learning experiences in the years to come. Integrating ICT into foundational courses, such as the compulsory community service course, signifies a monumental shift in the educational paradigm, reshaping pre-service preschool teachers' teaching and learning landscape in previously unimagined ways.

References

- Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers and Education*, 52(1), 154–168. <https://doi.org/10.1016/j.compedu.2008.07.006>
- Annelly, M. (2006). Triangulation of qualitative approaches: Hermeneutical phenomenology and grounded theory. *Journal of Advanced Nursing*, 56(1), 55–61. <https://doi.org/10.1111/j.1365-2648.2006.03979.x>
- Asorey, E., & Gil, J. (2009). El placer de usar las tic en el aula de infantil. *Participación Educativa*, 12, 110–119.
- Bas, G., Kubiato, M., & Murat, A. (2016). Teachers' perceptions towards ICTs in teaching-learning process: Scale validity and reliability study. *Computers in Human Behavior*, 61, 176–185. <https://doi.org/10.1016/j.chb.2016.03.022>
- Blackwell, C. K., Lauricella, A. R., Wartella, E., Robb, M., & Schomburg, R. (2013). Adoption and use of technology in early education: The interplay of extrinsic barriers and teacher attitudes. *Computers and Education*, 69, 310–319. <https://doi.org/10.1016/j.compedu.2013.07.024>
- Blackwell, C. K., Lauricella, A. R., & Wartella, E. (2014). Factors influencing digital technology use in early childhood education. *Computers & Education*, 77(2014), 82–90. <https://doi.org/10.1016/j.compedu.2014.04.013>

- Bocconi, S., & Panesi, S. (2018). Teachers' professional learning and competence in the digital era: The DigCompEdu framework. *Media Education: Studi, Ricerche, Buone Pratiche*, 39. <https://doi.org/10.4399/97888255210234>
- Bolstad, R. (2004). *The role and potential of ICT in early childhood education: A review of New Zealand and international literature* (Ministry of Education, Ed.). New Zealand Council for Educational Research.
- Brevik, L. M., Gudmundsdottir, G. B., Lund, A., & Stromme, T. A. (2019). Transformative agency in teacher education: Fostering professional digital competence. *Teaching and Teacher Education*, 86(102875), 1–15. <https://doi.org/10.1016/j.tate.2019.07.005>
- Brown, C. P., Englehardt, J., & Mathers, H. (2016). Examining pre-service teachers' conceptual and practical understandings of adopting iPads into their teaching of young children. *Teaching and Teacher Education*, 60, 179–190. <https://doi.org/10.1016/j.tate.2016.08.018>
- Cabezas, M., Casillas, S., & Pinto, A. M. (2014). Percepción de los alumnos de educación primaria de la universidad de salamanca sobre su competencia digital. *EDUTEc. Revista Electrónica De Tecnología Educativa*, 48, 10.21556/edutec.2014.48.156.
- Casillas, S., & Cabezas, M. (2014). Percepción de los alumnos de educación primaria de la universidad de salamanca sobre su competencia digital. *Revista Didáctica, Innovación y Multimedia*, 29. <http://dim.pangea.org/revista29.htm>
- Clements, D. H., & Sarama, J. (2003). Strip mining for gold: Research and policy in educational technology-A response to. *Educational Technology Review*, 11(1), 7–69.
- Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th Edition, SAGE Publications, Inc., London.
- Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Harvard University Press.
- Dong, Y., Xu, C., Chai, C., & Zhai, X. (2020). Exploring the structural relationship among teachers' technostress, technological pedagogical content knowledge (TPACK), computer self-efficacy, and school support. *Asia-Pacific Educational Research*, 29(2), 147–157.
- Enochsson, A.-B. (2010). *ICT in initial teacher training: Swedish report*. OECD.
- Farjon, D., Smits, A., & Voogt, J. (2019). Technology integration of pre-service teachers explained by attitudes and beliefs, competency, access, and experience. *Computers & Education*, 130, 81–93.
- Farmer, L. (2016). Incorporating information literacy into instructional design within pre-service teacher programs. In Information Resources Management Association (Ed.), *Professional development and workplace learning: Concepts, methodologies, tools, and applications*. Business Science Reference, An Imprint of IGI Global.
- Fernández, J. M., & Bermejo, B. (2012). Actitudes Docentes Hacia Las TIC En Centros De Buenas Prácticas Educativas Con Orientación Inclusiva. *Enseñanza Y Teaching. Revista Interuniversitaria De Didáctica*, 30(1), 45–61.
- Fernández, J. M., & Torres, J. A. (2015). Actitudes Docentes Y Buenas Prácticas Con TIC Del Profesorado De Educación Permanente De Adultos En Andalucía. *Revista Complutense De Educación*, 26(3), 33–49.
- Flick, U. (2014) *An Introduction to Qualitative Research*. 5th Edition, Sage Publications, London.
- Gayatri, M. (2020). The implementation of early childhood education in the time of Covid-19 pandemic: A systematic review. *Humanities & Social Sciences Reviews*, 8(6), 46–54. <https://doi.org/10.18510/hssr.2020.866>
- Gözüm, A. İ. C. (2022). Digital games for STEM in early childhood education: Active co-playing parental mediation and educational content examination. In S. Papadakis & M. Kalogiannakis (Eds.), *STEM, robotics, mobile apps in early childhood and primary education* (Lecture notes in educational technology). Springer. https://doi.org/10.1007/978-981-19-0568-1_21
- Gözüm, A. İ. C., & Demir, Ö. (2021). Technological pedagogical content knowledge self-confidence of prospective preschool teachers for science education during the COVID-19 period: A structural equation modelling. *International Journal of Curriculum and Instruction*, 13(1), 712–742.

- Gözümler, A. İ. C., & Kandır, A. (2021). Digital games preschoolers play: Parental mediation and examination of educational content. *Education and Information Technologies*, 26(3), 3293–3326.
- Gözümler, A. İ. C., Papadakis, S., & Kalogiannakis, M. (2022). Preschool teachers' STEM pedagogical content knowledge: A comparative study of teachers in Greece and Turkey. *Frontiers in Psychology*, 13, 996338. <https://doi.org/10.3389/fpsyg.2022.996338>
- Gözümler, A. İ. C., Metin, Ş., Uzun, H., & Karaca, N. H. (2023). Developing the teacher self-efficacy scale in the use of ICT at home for preschool distance education during Covid-19. *Technology, Knowledge and Learning*, 28(3), 1351–1381.
- Gretter, S., & Yadav, A. (2018). What do pre-service teachers think about teaching media literacy? An exploratory study using the theory of planned behaviour. *Journal of Media Literacy Education*, 10(1), 104–123.
- 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>
- Gur, H., & Karamete, A. (2015). A short review of TPACK for teacher education. *Academic Journals*, 10(7), 777–789. <https://doi.org/10.5897/ERR2014.1982>
- Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, 41(4), 393–416.
- Hatzigianni, M., & Margetts, K. (2012). 'I am very good at computers': Young children's computer use and their computer self-esteem. *European Early Childhood Education Research Journal*, 20(1), 3–20.
- Heitink, M., Voogt, J., Fisser, P., Verplanken, L., & van Braak, J. (2017). Eliciting teachers' technological pedagogical knowledge. *Australasian Journal of Educational Technology*, 33(3), 96–109. <https://doi.org/10.14742/ajet.3505>
- Howard, J., Miles, G. E., & Rees-Davies, L. (2012). Computer use within a play-based early years curriculum. *International Journal of Early Years Education*, 20(2), 175–189.
- Hu, X., & Yelland, N. (2017). An investigation of pre-service early childhood teachers' adoption of ICT in a teaching practicum context in Hong Kong. *Journal of Early Childhood Teacher Education*, 38(3), 259–274. <https://doi.org/10.1080/10901027.2017.1335664>
- ISTE. (2017). *International society for technology in education standards for educators*. International Society for Technology in Education.
- Jack, C., & Higgins, S. (2019). Embedding educational technologies in early years education. *Research in Learning Technology*, 27, 2033.
- Jimoyiannis, A., & Komis, V. (2007). Examining teachers' beliefs about ICT in education: Implications of a teacher preparation program. *Teacher Development*, 11(2), 149–173. <https://doi.org/10.1080/13664530701414779>
- Judge, S., Puckett, K., & Bell, S. (2006). Closing the digital divide: Update from the early childhood longitudinal study. *The Journal of Educational Research*, 100, 52–60. <https://doi.org/10.3200/JOER.100.1.52-60>
- Kabadayı, A. (2006). Analyzing preschool student teachers' and their cooperating teachers' attitudes towards the use of educational technology. *TOJET: The Turkish Online Journal of Educational Technology*, 5(4), 3–10.
- Kalas, I. (2010). *Recognizing the potential of ICT in early childhood education*.
- Kalogiannakis, M., & Papadakis, S. (2017, August 21–25). *Pre-service kindergarten teachers' acceptance of "ScratchJr" as a tool for learning and teaching computational thinking and Science education*. In Proceedings of the 12th conference of the European Science Education Research Association (ESERA), research, practice and collaboration in science education, Dublin.
- Kalogiannakis, M., & Papadakis, S. (2019). Evaluating pre-service kindergarten teachers' intention to adopt and use tablets into teaching practice for natural sciences. *International Journal of Mobile Learning and Organisation*, 13(1), 113. <https://doi.org/10.1504/ijmlo.2019.096479>

- Kim, J. (2020). Learning and teaching online during Covid-19: Experiences of student teachers in an early childhood education practicum. *International Journal of Early Childhood*, 52(2), 145–158. <https://doi.org/10.1007/s13158-020-00272-6>
- Knezek, G., & Christensen, R. (2016). Extending the will, skill, tool model of technology integration: Adding pedagogy as a new model construct. *Journal of Computing in Higher Education*, 28(3), 307–325.
- Kocadere, S. A., & Seferoğlu, S. S. (2013). Topluma hizmet uygulamaları dersinin işlenişi: uygulama örnekleri ve sürece ilişkin öğrenci görüşlerinin değerlendirilmesi. *Pamukkale Üniversitesi Eğitim Fakültesi Dergisi*, 34, 75–89.
- Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60–70. Retrieved November 7, 2020, from <https://www.learntechlib.org/primary/p/29544/>
- Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, 193(3), 13–19. <https://doi.org/10.1177/002205741319300303>
- Konca, A. S., Özel, E., & Zelyurt, H. (2016). Attitudes of preschool teachers towards using information and communication technologies (ICT). *International Journal of Research in Education and Science (IJRES)*, 2(1), 10–15.
- Krumsvik, R. J. (2011). Digital competence in Norwegian teacher education and schools. *Högskoleutbildning*, 1, 39–51.
- Krumsvik, R. J. (2014). Teacher educators' digital competence. *Scandinavian Journal of Educational Research*, 58, 269–280. <https://doi.org/10.1080/00313831.2012.726273>
- Masoumi, D. (2015). Preschool teachers' use of ICTs: Towards a typology of practice. *Contemporary Issues in Early Childhood (CIEC)*, 16(1), 5–17.
- McKenney, S., & Voogt, J. (2012). Teacher design of technology for emergent literacy: An explorative feasibility study. *Australasian Journal of Early Childhood*, 37(1), 4–12.
- Merriam, S. B. (2013). *Qualitative Research: A Guide to Design and Implementation*. John Wiley & Sons Inc., New York.
- Neuman, W. (2014). *Social Research Methods: Qualitative and Quantitative Approaches*. Pearson, Essex, UK.
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054.
- Nikolopoulou, K., & Gialamas, V. (2015). Barriers to the integration of computers in early childhood settings: Teachers' perceptions. *Education and Information Technologies*, 20, 285–301. <https://doi.org/10.1007/s10639-013-9281-9>
- Papadakis, S., & Kalogiannakis, M. (2020). A research synthesis of the educational value of self-proclaimed mobile educational applications for young age children. In S. Papadakis & M. Kalogiannakis (Eds.), *Mobile learning applications in early childhood education* (pp. 1–19). IGI Global. <https://doi.org/10.4018/978-1-7998-1486-3.ch001>
- Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2018). Educational apps from the android Google Play for Greek preschoolers: A systematic review. *Computers & Education*, 116(139), 160. <https://doi.org/10.1016/j.compedu.2017.09.007>
- Papadakis, S., Gözümlü, A. İ. C., Kalogiannakis, M., & Kandır, A. (2022). A comparison of Turkish and Greek parental mediation strategies for digital games for children during the COVID-19 Pandemic. In S. Papadakis & M. Kalogiannakis (Eds.), *STEM, robotics, mobile apps in early childhood and primary education* (Lecture notes in educational technology). Springer. https://doi.org/10.1007/978-981-19-0568-1_23
- Peeraer, J., & Van Petegem, P. (2011). ICT in teacher education in an emerging developing country: Vietnam's baseline situation at the start of 'The Year of ICT'. *Computers & Education*, 56(4), 9.
- Petko, D. (2012). Teachers' pedagogical beliefs and their use of digital media in classrooms: Sharpening the focus of the 'will, skill, tool' model and integrating teachers' constructivist orientations. *Computers & Education*, 58, 1351–1359.
- Ploughman, M., Austin, M. W., Murdoch, M., Kearney, A., Godwin, M., & Stefanelli, M. (2012). The path to self-management: A qualitative study involving older people with multiple sclerosis. *Physiotherapy Canada*, 64(1), 6–17.

- Plowman, L., McPake, J., & Stephen, C. (2008). Just picking it up? Young children learning with technology at home. *Cambridge Journal of Education*, 38(3), 303–319.
- Plowman, L., McPake, J., & Stephen, C. (2012). Extending opportunities for learning: The role of digital media in early education. In S. Suggate & E. Reese (Eds.), *Contemporary debates in childhood education and development* (pp. 96–112). Routledge.
- Rambousek, V., Stípek, J., & Vanková, P. (2016). Contents of digital literacy from the perspective of teachers and pupils. *Procedia, Social and Behavioral Sciences*, 217, 354–362. <https://doi.org/10.1016/j.sbspro.2016.02.101>
- Redecker, C., & Punie, Y. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publication Office of the European Union. <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/european-framework-digital-competence-educators-digcompedu>
- Roussinos, D., & Jimoyiannis, A. (2019). Examining primary education teachers' perceptions of TPACK and the related educational context factors. *Journal of Research on Technology in Education*, 51(4), 377–397. <https://doi.org/10.1080/15391523.2019.1666323>
- Samuelsson, R. (2019). Embodied reasoning with digital tools in the preschool ecology: Science learning beyond digital/analogue dichotomies. In *EDULEARN19 proceedings* (pp. 5159–5163). IATED.
- Scott, J. (2014). *A Dictionary of Sociology*, Oxford University Press, Oxford.
- Seferoğlu, S. S. (2004). Öğretmen yeterlikleri ve mesleki gelişim. *Bilim ve Aklın Aydınlığında Eğitim*, 58, 40–45.
- Seufert, S., Guggemos, J., & Sailer, M. (2021). Technology-related knowledge, skills and attitudes of pre- and in-service teachers: The current situation and emerging trends. *Computers in Human Behavior*. <https://doi.org/10.1016/j.chb.2020.106552>
- Siddiq, F., & Scherer, R. (2016). The relation between teachers' emphasis on the development of students' digital information and communication skills and computer self-efficacy: The moderating roles of age and gender. *Large-Scale Assessments in Education*, 4(1), 17.
- Simsar, A., & Kadim, M. (2017). Okul öncesi öğretmenlerinin bilişim teknolojilerini kullanma durumları ve bunun öğretime etkisi. *Kilis 7 Aralık Üniversitesi Sosyal Bilimler Dergisi*, 7(14), 127–146.
- Siraj-Blatchford, I., & Siraj-Blatchford, J. (2003). *More than computers: Information and communication technology in the early years*. The British Association for Early Childhood Education.
- Tiede, J. (2020). Conclusions: Media-related educational competencies of German and US pre-service teachers. *MedienPädagogik*, 221–235.
- Tiede, J., Grafe, S., & Hobbs, R. (2015). Pedagogical media competencies of pre-service teachers in Germany and the United States: A comparative analysis of theory and practice. *Peabody Journal of Education*, 90(4), 533–545.
- Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, 59(1), 134–144. <https://doi.org/10.1016/j.compedu.2011.10.009>
- Tondeur, J., Aesaert, K., Pynoo, B., van Braak, J., Fraeyman, N., & Erstad, O. (2017). Developing a validated instrument to measure pre-service teachers' ICT competencies: Meeting the demands of the 21st century. *British Journal of Educational Technology*, 48(2). <https://doi.org/10.1111/bjet.12380>
- Tondeur, J., Aesaert, K., Prestridge, S., & Consuegra, E. (2018). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education*, 122, 32–42.
- UNESCO. (2022). *UNESCO Guidelines for ICT in education policies*. <https://digital-skills-jobs.europa.eu/en/inspiration/research/unesco-guidelines-ict-education-policies-2022>
- Yelland, N. (2007). *Shift to the future: Rethinking learning with new technologies in education*. Routledge.
- Yıldırım, A. & Şimşek, H. (2016). Sosyal bilimlerde nitel araştırma yöntemleri. Ankara: Seçkin

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