Revolutionising education: the evolution, current landscape and future of digital learning

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Abstract: The history of digital learning dates back to the late 20th century, evolving rapidly with computer technology. Initially computer-based online learning offered flexibility. Mobile learning followed, enabling access via smartphones or tablets. As technology progressed, seamless learning emerged, allowing fluid device transitions. Blended learning combined traditional and online methods for a richer experience. Game-based learning increased engagement through gaming elements. Immersive learning, utilising Virtual Reality (VR) and Augmented Reality (AR) technologies, enhanced content experience. Future digital learning trends towards personalisation, intelligence, and interactivity, reshaping education. Through continuous innovation and integration of various technological tools, digital learning will provide students with more personalised and engaging learning experiences, helping them better grasp knowledge and skills to meet future challenges.

Keywords: digital learning; online learning; mobile learning; seamless learning; blended learning; game-based learning; immersive learning.

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1 The evolution of digital learning

The concept of digital learning can be traced back to the late 20th century. In Negroponte (1997), American computer scientist described a virtual survival environment in his book Being Digital, where people could work, learn and entertain themselves. Negroponte viewed digital learning as a fundamental survival skill in the digital age. Subsequently, the first networked Learning Management System (LMS), called Cecil, was introduced in 1997 (Bezhovski and Poorani, 2016). This software application could be used to organise, record and deliver digital learning courses. Digital learning, supported by Learning Management Systems, began to gain popularity. Modern Learning Management Systems are capable of providing various types of learning content, including but not limited to reading materials, videos, audio, web conferences, forums, blogs, etc.

In 1998, American scholar Cross (2004) first introduced the concept of e-learning. The full English term for e-learning is Electronic Learning, which can be translated into Chinese as digital learning, electronic learning or online learning. Although these translations emphasise different aspects, all three underscore the reshaping of learning through digital technology (Yang and Ren, 2017). The US Department of Education (2001) issued the Education Technology White Paper, the earliest education department document globally to mention the concept of digital learning. This document provided a comprehensive discussion on digital learning (US Department of Education, 2001), presenting seven interpretations of the essence of digital learning (as shown in Figure 1). That same year, the European Commission released the e-Learning action plan: Designing Tomorrow's Education, which outlined the principles, goals and action plan of digital learning. It defined digital learning as a new learning method that utilises new multimedia technologies and the internet to access resources and services, enabling remote communication and collaboration to enhance learning quality (Commission of the European Communities, 2001).

Domestic researchers have also provided different definitions of digital learning. Li (2017) believed that digital learning refers to the learning process in which learners utilise digital learning resources in a digital learning environment (Zhang et al., 2015). It includes three basic elements: digital learning environment, digital learning resources and digital learning methods. He (2002) pointed out that e-learning refers to learning and teaching activities conducted via the internet, representing a new way of learning in a learning environment that fully utilises modern information technology, offering new communication mechanisms and rich resources.

Taking a comprehensive view, the above-mentioned domestic and foreign institutions have all highlighted a key point about digital learning, which is that digital learning involves learning activities conducted using information technology. Digital learning not only transforms the role of teachers and the relationship between teachers and students in traditional education but also reshapes the way learners learn, exerting a significant impact on the education system.

Figure 1   Interpretation of the essence of digital learning according to the US Educational Technology White Paper (see online version for colours)
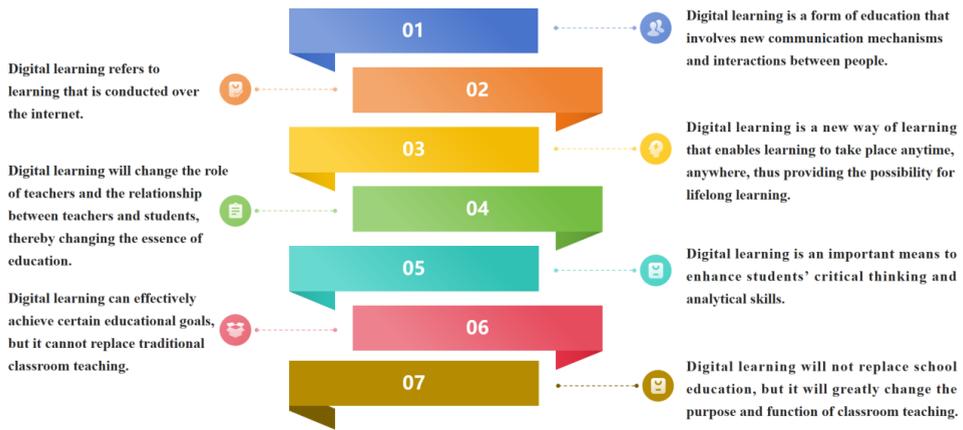
Digital learning has had a significant impact on educational reform. It utilises multimedia technology and the internet to enhance the quality of learners' education, helping them access rich resources and services, engage in remote communication and collaboration and ensuring that learners can freely access online digital resources at any time and from any location (Ehlers and Pawlowski, 2006). Digital learning is typically divided into two types: synchronous training and asynchronous training (Bezhovski and Poorani, 2016). Synchronous learning involves teachers and learners participating in digital learning activities simultaneously over the internet, with communication between them facilitated through webinars, instant messaging, video chats and the like (Rosen, 2009). On the other hand, in asynchronous learning, teachers typically pre-publish content, allowing learners to study at their own pace and according to their own needs (Rosen, 2009).

With the continuous development of digital technology, various modes of digital learning have emerged, such as online learning, mobile learning, seamless learning, blended learning, game-based learning and immersive learning. These modes fully utilise digital technology to empower traditional learning, making learning more flexible and convenient, providing learners with richer learning experiences and injecting new vitality into traditional learning models. According to authors like Yang and Liu (2023) on their definition of digital learning, digital learning mainly includes six modes.

2   The current landscape of digital learning

2.1   Online learning

The development of modern information technology has profoundly influenced the way humans learn, leading to significant changes in the field of education. Online education has become an important educational tool and is widely used in various levels and types of education. Massive Open Online Courses (MOOCs), micro-courses, flipped classrooms and others are all products of online education.

Khan (1997) defined online learning as a way of providing teaching remotely to audiences through the internet. Carliner (1999) defined online learning as presenting educational materials on a computer. However, the focus of online learning is not only about what network or technology researchers use, but how learners engage in learning. According to Bonk and Reynolds (1997), to develop learners' higher-order thinking, online learning must create challenging activities that allow learners to connect new and old knowledge, use metacognitive learning abilities and gain meaningful learning experiences. Therefore, researchers believe that teaching strategies, rather than the technology itself, affect the quality of learning. Kozma (2001) believed that computers themselves cannot provide beneficial learning activities for learners; learners acquire knowledge by interacting with the content in the computer, with the computer serving only as a tool for learning (Clark, 2001).

As teaching gradually shifts from traditional media to computer-based media, online learning has received widespread attention. The Educational Technology White Paper released by the US Department of Education (2001) pointed out that online learning is primarily a mode of education conducted through networks, where learners can engage in learning through professional websites, electronic libraries, online classrooms and other channels, thus providing opportunities for lifelong learning (Li, 2017). Driscoll believes that online learning enables learners to access materials and engage in learning through the internet (Li, 2017). Chinese scholar Nan considers online learning to be a learner-centred mode of learning primarily conducted through multimedia networks (Li, 2017).

The cognitive load theory of the 1990s is closely related to online learning. According to the cognitive load theory, learners have limited cognitive capacity in their working memory. The total cognitive load experienced by learners consists of three parts: extraneous cognitive load, intrinsic cognitive load, and germane cognitive load. Extraneous cognitive load refers to cognitive processing caused by the presentation format of the learning material that is unrelated to the learning objectives; intrinsic cognitive load is the cognitive processing required to achieve the learning objectives and germane cognitive load is the cognitive processing induced by the learner's effort (Sweller, 1999).

In addition to the cognitive load theory, constructivism also influences online learning. As learners find themselves in the era of information explosion, future learners need to become independent critical thinkers, learn to discern genuinely useful information, stay updated on developments in their fields and acquire necessary knowledge. Furthermore, learners must learn to share viewpoints with other internet users worldwide, establish connections, access learning resources through various channels and strive for optimal learning states (Mukhopadhyay and Parhar, 2001). Additionally, due to information overload, future learners must be willing to continuously acquire new knowledge, while future educators should design learning experiences that promote authenticity and encourage students to become lifelong learners (Schmidt and Werner, 2007).

For learners, online learning transcends the limitations of time and space. In asynchronous online learning, students can access online learning materials at any time, while synchronous online learning allows for real-time interaction between students and teachers. Learners can use the internet to access the latest learning materials and engage with experts in relevant fields. For teachers, instructional activities can take place anytime and anywhere. They can adapt to learners' online feedback, understand their needs promptly and provide more suitable materials (Ally, 2008; Chen et al., 2024; Jiang

et al., 2021, 2022). Online learning can increase people's access to education and training, enhance learning quality, reduce costs and improve efficiency. However, many platforms experience high student dropout rates (Perna et al., 2014), and online education also demands higher levels of self-discipline from students (Allen and Seaman, 2006).

2.2   *Mobile learning*

The development of mobile technology has ushered in a new era of digital learning known as the era of mobile learning. Mobile phones, smartphones, tablets and other devices have all benefited from mobile technology (Traxler and Kukulska-Hulme, 2005). By using these devices, learners are not constrained by geographical limitations and can make full use of fragmented time for learning.

Mobile learning refers to a way of learning where learners can study at any time and any place with the assistance of mobile devices. The mobile computing devices used in mobile learning must effectively present learning content while providing channels for communication between teachers and learners. Harris and Quinn believed that mobile learning is an extension of digital learning, with both sharing similarities in learning but differing in how information is accessed, as mobile learning primarily relies on mobile communication networks and devices (Ye et al., 2004). Harris views mobile learning as the intersection of mobile computing technology and digital learning, enabling learners to study anytime and anywhere. Crompton (2013) defined mobile learning as using personal electronic devices to learn in various environments and engage in social interactions with others. Mobile learning can take place both inside and outside the classroom, allowing learners to participate in prescribed courses on mobile devices or independently explore content of interest on their mobile devices for self-directed learning.

In the 21st century, with the advent of smartphones, tablets and other mobile devices that offer similar applications and functionalities to handheld computers but are more portable, interest in handheld computers has waned. In 2005, mobile learning became a recognised academic term. As mobile learning continues to evolve, Traxler and Wishart (2011) pointed out that mobile learning provides learners with new learning opportunities in five ways: learning based on real-world situations, contextual learning, promoting authentic learning, fostering situational awareness learning and personalised learning.

Mobile learning is closely linked to social constructivism. Constructivism views learning as a process where learners construct new knowledge themselves, while social constructivism sees learning as an active engagement with the community (Brown, 2006), where new meaning is co-constructed by learners and the 'community'. Tsipursky (2013) coined the term 'class-sourcing' as a teaching strategy to help educators stay connected with learners in the digital age. Tsipursky suggests that learners can research topics of their choice by accessing online digital artifacts such as blogs, videos, podcasts, analyse gathered information and share and discuss with peers, fostering research skills and critical thinking.

Furthermore, Navigationism is also associated with mobile learning. Navigationism is a learning paradigm that emphasises learners discovering, identifying, evaluating information and knowledge during the learning process and integrating this knowledge into work and life to solve real-world problems. Brown (2006) emphasised that effective learning occurs when learners actively engage in solving real-life problems through communication and collaboration. The focus of learning should not be solely on

acquiring and creating knowledge during the learning process, but on problem-solving, with teachers playing the role of guides in this process.

Mobile learning is highly favoured for its flexibility, enabling learning to take place anywhere, both inside and outside the classroom. It provides potential opportunities for collaborative learning and enriches learners' learning experiences with technological support (Looi et al., 2012). Since 2000, distance education and higher education institutions in Africa have been encouraging the use of SMS functionality on mobile phones by teachers and students, facilitating timely communication among them and integrated into most learning management systems (UNESCO, 2012). Learners can also use smartphones and tablets to access various messages on social platforms in real-time, communicate via Bluetooth, send emails and engage with others.

Additionally, learners can establish their own learning communities through web-based applications and social media, interacting with other online learners (Brown and Mbati, 2015). Despite the numerous advantages of mobile learning, there are also some drawbacks. Mobile devices may sometimes fail to connect to the internet due to inadequate cellular network coverage or wireless communication link failures. Compared to computers, mobile devices have limited storage space, relatively smaller screens and battery life that needs improvement. Some teachers and students believe that mobile devices can cause distractions, consequently affecting students' academic performance (Criollo et al., 2018).

2.3   Seamless learning

The aim of seamless learning is to eliminate gaps, enabling learners to seamlessly switch between different contexts, such as formal and informal settings, individual learning and social learning. Seamless learning expands learners' learning spaces and promotes mutual communication among learners.

Seamless learning has two important features: seamless adaptivity and seamless connectivity. Seamless adaptivity refers to technology adapting to learners without their explicit knowledge, e.g., providing suitable learning content based on the learners' pace and language preferences. Seamless connectivity enables technology to help learners resume learning from where they left off, as well as allows learners to promptly recall previous learning content through search, ensuring continuity in learning (Milrad et al., 2013).

Research on seamless learning originates in two main types. The first type originated in the higher education sector. Kuh (1996) proposed a set of principles aimed at cultivating a seamless learning culture in universities. These principles advocated for the integration of formal and informal learning, altering students' learning methods and lifestyles and systematically reforming American universities. At that time, the research did not yet involve scientific and technological factors. Entering the 21st century, with the emergence of computer science and mobile learning, more and more learners had the opportunity to directly use their electronic devices. Researchers began to focus on the application of technology in seamless learning. Chan et al. (2006) introduced the concept of a 'seamless learning space,' where learners could transcend different learning environments through electronic devices, experiencing the continuity of learning. The concept of 'technology-enhanced learning' also began to emerge, marking the second type of origin in seamless learning research. Wong and Looi (2019) presented a

framework encompassing ten characteristics of seamless learning, integrating the two types of seamless learning research together.

Sharples et al. (2012) defined seamless learning as the continuity of learning experienced by an individual across different times, locations, technologies or social environments, potentially spanning a person's entire lifetime. Ozdamli (2013) highlighted that seamless learning makes learning more personalised and meaningful as it is student-centred, requiring students to think independently, learn actively and solve problems, thus facilitating the construction of new knowledge by students. That same year, Milrad et al. (2013) pointed out that true seamless learning transforms all learning resources accessible to learners into tools to aid them in constructing knowledge. Wong (2015) proposed that seamless learning involves learners consciously crossing time, location and social environments for continuous learning. The evolution of the seamless learning concept demonstrates that this mode of learning not only provides learners with cross-contextual learning opportunities but also encourages a shift in learners' learning habits.

Seamless learning is closely linked to the theory of distributed cognition. Hollan et al. (2000) proposed the theory of distributed cognition, outlining three principles of cognitive processes: cognition occurs within social groups, has a temporal dimension and involves coordination between internal and external structures of cognitive systems. In seamless learning, learning can take place through individual learning in private learning spaces, collaborative learning in public learning spaces, and more. Wong and Looi (2019) designed a set of principles to support learners' cognitive and social processes, facilitating seamless learning. These principles mainly include the design of connected learning spaces, social constructivist inquiry-based learning, formative assessment of student work, utilisation of resources in informal environments and personalised and self-directed learning.

With the advent of the digital age, seamless learning enables learners to effortlessly navigate between the physical and digital worlds. The boundaries between classroom learning and extracurricular learning are becoming increasingly blurred (Zhu and Sun, 2015). Learners can switch between different learning environments, learning objectives and tasks, accessing information and knowledge from various fields. Learners themselves can become the centre of learning, continuously constructing knowledge (Wang, 2018), thus ensuring the continuity of learning (Dilger et al., 2019). Seamless learning combines formal and informal learning, making learning methods more open and flexible, enriching learners' learning experiences. However, seamless learning also faces certain challenges. For educational practitioners, further exploration is needed on how to better utilise technology to guide students in seamless learning. Seamless learning also places high demands on learners' autonomy (Zhu and Sun, 2015).

2.4   Blended learning

Blended learning is a learning approach that combines face-to-face learning with online learning (Bonk and Graham, 2006), seen as an extension of distance and online learning (Deniz, 2024). Initially, blended learning was perceived as a simple mix of online and face-to-face instruction. However, as research progressed, more and more researchers realised that the term blended should be understood as integration or fusion, rather than just a combination (Liu et al., 2024). Blended learning goes beyond the mere merging of

learning environments; it involves the reintegration of various elements such as learning resources, teaching strategies, learning tools, instructional modes and more.

Voci and Young (2001) incorporated blended learning into a six-month leadership training program. The results of this study indicated that students' sense of teamwork was enhanced, and the learning efficiency of each group was improved. Bonk et al. (2002) utilised blended learning methods in military courses to teach students, exploring the impact of this approach on students' professional development. The study results revealed that despite the appeal of online learning for its engaging and flexible nature, most learning still occurred during face-to-face interactions between teachers and students.

Osguthorpe and Graham (2003) provided the following definition of blended learning: Blended learning is the combination of face-to-face learning with distance learning, where learners utilising blended learning modes strive to maximise the advantages of both face-to-face and online learning methods. Additionally, they introduced three different blended learning modes: blend of learning activities, blend of students and blend of instructors (Osguthorpe and Graham, 2003). Blend of learning activities refers to the same student benefiting from both face-to-face classroom activities and online learning activities. Blend of students involves students in face-to-face classrooms interacting with different students in online learning environments. Blend of instructors means that students in face-to-face classrooms can interact with different instructors through online learning environments. That same year, Singh (2003) defined dimensions that can be blended in blended learning, including offline and online learning, self-paced learning and collaborative learning, structured learning and unstructured learning, among others.

The research by Garrison and Kanuka (2004) is a highly cited article in the field of blended learning. Researchers explored the potential of blended learning in higher education, highlighting that blended learning combines the face-to-face classroom experience with online learning experiences. The adoption of blended learning in higher education positively impacts schools' policy-making, resource allocation and scheduling. Carman (2005) noted that blended learning is a blend of cognitivism, constructivism and performance technology theories. He outlined five key elements that constitute the blended learning process: real-time activities, online content, collaboration, assessment and relevant resources (such as e-textbooks, videos and audio). That same year, the U.S. Educause Research Center (Zou, 2005) pointed out that blended learning helps address challenges in cost, effectiveness and accessibility for higher education institutions. Blended learning also influences the development and salaries of teaching staff, department structures, student learning and alumni relationships within universities, indicating that blended learning is a driving force for institutional transformation (Zou, 2005). In April 2005, at a conference on Higher Education and Blended Learning organised by the Sloan Consortium, over 30 participating schools agreed that blended learning prompts a re-evaluation of teaching and learning methods and has the potential to impact the current educational landscape (Zou, 2005). In 2007, a research report titled 'Current Situation and Prospects of Blended Learning in the United States' was jointly released by the Basbson research group, the Sloan Consortium and Edubentures. This report highlighted the significant development opportunities and prospects for blended learning and online learning (Allen et al., 2007). Graham (2006) summarised the background, definition, trends, blended categories, challenges and future directions of blended learning.

In the realm of theoretical research on blended learning, Chinese scholar He et al. (2005) proposed that the applicable educational ideology in China is neither teacher-centred nor student-centred. Instead, it emphasises the combined leadership role of teachers and the prominent position of students in the learning process, termed as a combination of leading and protagonism. Information technology is seen not just as a tool for assisting teachers in teaching or aiding students in learning, but should be organically integrated with subject curricula. In the mid-1990s, the international educational technology community leaned more towards student-centred instructional design, emphasising aspects such as scenario creation, collaborative learning and the design of autonomous learning strategies, while overlooking instructional goal analysis, learner characteristics and the role of teacher guidance. With the development of blended learning theory, instructional design gradually merged the teacher-centred and student-centred approaches, forming a teaching design ideology that values both teaching and learning equally. The leading-protagonism learning theory emphasises the roles of both teachers and students, highlighting that blended learning requires a comprehensive consideration of student needs and the implementation challenges faced by teachers. Khan (2003) introduced the Octagonal Framework for blended learning. He pointed out that when creating a meaningful blended environment, all eight elements should be taken into account, as most of these elements are interconnected and interdependent. These eight elements include institutional elements, instructional elements, technological elements, interface design elements, assessment elements, management elements, resource support elements and ethical elements. This framework provides a macroscopic examination of the conditions for implementing blended learning and outlines the extension of the blended learning activity system.

Numerous studies indicate that learners prefer web-based online learning environments, yet they are also unwilling to relinquish traditional face-to-face classroom settings (Chen and Jones, 2007; So and Brush, 2008; Akkoyunlu and Soylu, 2008; Chandra and Fisher, 2009; Smyth et al., 2012). Miyazoe and Anderson (2010) expressed that the format of blended learning is engaging, innovative and fosters positive learning experiences. They have also researched the impact of blended learning on learners' academic performance, satisfaction, motivation and attitudes. The research findings show that learners utilising blended learning do not exhibit significant differences in academic performance compared to those using traditional learning methods. However, learners in blended learning environments demonstrate higher levels of satisfaction, motivation and positive attitudes (El-Deghaidy and Nouby, 2008; Woltering et al., 2009; Jia et al., 2012). Additionally, blended learning can reduce dropout rates and improve learners' pass rates in exams (López-Pérez et al., 2011). In studies on blended learning, there has been no significant observed impact on learners' critical thinking abilities (Akyüz and Samsa, 2009). However, blended learning is not suitable for all courses. This learning model requires a larger number of instructional and administrative staff and involves significant communication and coordination efforts. Before a course begins, teachers need to plan and delegate tasks effectively, create online materials, integrate relevant teaching resources, arrange appropriate instructors and teaching assistants and ensure that all student activities progress smoothly throughout the learning process. Therefore, the human and management costs associated with blended learning are relatively high. Typically, this approach is more suitable for courses with a large number of trainees (Zhan, 2011).

2.5 Game-based learning

Game-based learning refers to the integration of elements from internet games into the learning process. Game-based learning makes the learning process more engaging and interesting, thus motivating learners to engage with the material (Prensky, 2003). The concept of Game-based learning can be traced back to as early as 2003, where it involves the application of game elements, game design and game principles into non-game contexts (Werbach and Hunter, 2014).

Researcher Egenfeldt-Nielsen (2007) once divided the application of games in education into three stages based on time. Firstly, game-based learning was initially influenced by behaviourist learning theory, emphasising control and feedback, focusing on the generation and reinforcement of behaviours. In this stage, the games used in game-based learning were largely operational games. Secondly, the research on the application of educational games flourished from the mid-1980s to the mid-1990s. This period of game-based learning took into account differences among learners. In the second-generation game applications, constructivist learning theory became mainstream, shifting the focus from behaviour to learners. It emphasised that each learner has their own prior knowledge, viewpoints and different plans. During this period, game applications focused on learners' own knowledge construction, advocating that game-based learning processes should be based on learners' free choices. This led to the development of educational games that effectively combined game formats with learning content, covering subjects like history, geography and architecture. Lastly, the third generation of game-based educational applications focused on the educational uses of computer games, emphasising the interactivity between student roles and the games themselves. Teachers, as facilitators, need to incorporate computer game experiences into the classroom. This generation of game-based learning emphasises how students use games for learning rather than the content of the games themselves.

Van Eck (2006) summarised four ways in which schools can implement game-based learning. Firstly, directly incorporating commercial games into classroom teaching involves using pre-developed games in the classroom to spark students' interest in learning based on the course content and achieve teaching objectives. Secondly, games developed by research institutions focus more on knowledge acquisition and are often designed from the teacher's instructional perspective. Thirdly, games developed by subject teachers involve integrating games into learning, requiring higher programming skills from the teachers. Lastly, teachers can organise students to design and develop games, a method that helps students grasp course content and enhances their learning motivation, although it demands a significant time commitment from the students.

In recent years, many researchers and frontline educators have been applying educational games to school education. Jenkins turned games into a classroom resource and utilised them in school teaching. One notable game is Revolution, a 3D multiplayer online game based on the American Revolution and historical events in the Williamsburg colony. Learners can engage in interactions and role-playing in a virtual environment to learn about American history. This game has been integrated into history classes in some American high schools (Zhuang et al., 2015). Given the difficulty for educational practitioners to independently develop a game software during actual teaching, many subject teachers directly incorporate commercial games into their teaching. This has led to the concept of applying pre-existing Commercial Off-The-Shelf (COTS) network games in teaching. For example, the Civilisation series is a commercial network game

where players can choose the direction of their civilisation's development, guiding their people from primitive societies to future societies. Squire conducted an experimental study using Civilisation in 2004 with fourth and ninth-grade students from a city high school, applying the game to history and geography learning. The 18-day experiment showed that students not only applied their knowledge of geography and history in solving game problems but also gained deeper insights into the progress of civilisations, enhancing their problem-solving skills. Additionally, through group competition, students developed teamwork abilities (Zhuang et al., 2015). World of Warcraft, developed by Blizzard Entertainment, is a large-scale online game with players from around the world. An American teacher used it in German language classes, encouraging students to communicate with players from Germany in the game to practice German listening, speaking, reading and writing skills (Zhuang et al., 2015).

In game-based learning, the game content and gameplay can help learners acquire knowledge and skills more effectively. By solving problems within games, learners can also experience a sense of achievement (Prensky, 2001). Furthermore, game-based learning can stimulate learners' curiosity, aid in self-expression, clarify goals, encourage collaboration and ultimately promote meaningful learning (Anderson, 2011; Squire, 2013). Additionally, game-based learning can enhance learner interactions, boost motivation, increase engagement and help develop essential 21st century skills such as collaboration, creativity, communication and critical thinking (Csikszentmihalyi, 1990; Shute, 2011). Despite the numerous advantages of game-based learning, designing games that balance educational value and entertainment remains a challenge. Many educational games are primarily developed by technology companies that often prioritise profit, potentially neglecting the educational aspects of the games. Moreover, electronic games require specific technology and infrastructure, leading to underprivileged regions facing challenges incorporating electronic games into education due to limited resources and funding (Aguilera and De Roock, 2022).

2.6   Immersive learning

Supported by Virtual Reality (VR) technology and Augmented Reality (AR) technology, digital media has connected virtual learning spaces with real-world learning spaces. This allows learners to immerse themselves in deeply immersive environments, experiencing a stronger sense of immersion, presence and interactivity. This also shapes embodied experiential learning in digital virtual learning spaces, known as immersive learning (Yang and Fan, 2024).

In the early 21st century, researchers began studying virtual reality. Schuemie et al. (2001) explored the effectiveness of virtual reality in psychological therapy. At that time, the role of VR was not fully understood, but today, it is increasingly recognised that VR can have significant impacts on various aspects of human life. Virtual reality technology has transformed how humans experience and interact with digital environments (Velev and Zlateva, 2017), allowing users to immerse themselves in computer-generated fictional worlds with a sense of presence. Augmented reality, on the other hand, enriches human real-world experiences by overlaying computer-generated virtual content onto the physical world. These two technologies have found applications in various fields such as healthcare, education, gaming and retail (Kamińska, 2019). The main features of virtual reality are immersion in a virtual world and interactivity, while augmented reality involves the merging of virtual and real worlds.

VR and AR technologies have the potential to transform traditional learning methods by providing immersive digital experiences and interactive environments, thereby improving the educational system. In recent years, the use of VR and AR technologies in education has been on the rise, offering learners valuable learning opportunities (Tan et al., 2022). Firstly, VR and AR technologies offer numerous benefits for online learning, mobile learning and blended learning. For instance, they can be used to create virtual worlds, allowing students to explore unseen environments without leaving the classroom (Young et al., 2020). Immersive and interactive learning through virtual and augmented reality also enables learners to immerse themselves in virtual environments, creating engaging interactive content that maintains high levels of learning engagement (Gargrish et al., 2020). Studies have shown that after integrating VR and AR technologies into classrooms, students exhibit increased levels of engagement, motivation and better task completion (Sun et al., 2023). This may be because VR and AR technologies provide learners with realistic experiences, allowing them to explore and interact with their surroundings. Secondly, VR and AR technologies provide students with practical training opportunities to develop vocational skills, making them more competitive in the future job market (Kurni et al., 2023). Additionally, these technologies can offer educators virtual teaching scenarios, bridging the gap between traditional classroom teaching and field experiences (Seidametova et al., 2021). VR and AR technologies are also utilised in informal education settings such as museums, science centres and libraries. By using VR and AR, students can gain insights into the natural world or ancient societies that are otherwise inaccessible in real life, leading to a deeper understanding of the knowledge presented in museums or science centres.

However, immersion also faces several challenges, with one of the main ones being the high costs associated with virtual reality and augmented reality learning (Nguyen an Dang, 2017). The hardware and software required for VR and AR technologies are often expensive, making it difficult for most schools to afford the necessary equipment due to budget constraints. Additionally, the software used to create immersive experiences needs regular updates, which further requires financial investment. Moreover, prolonged use of VR and AR devices may have negative impacts on users' health, such as eye strain, headaches and users may also be at risk of falling while wearing VR or AR devices (Siricharoen, 2023).

3   The future trends of digital learning

With the continuous progress and widespread adoption of technology (Du et al., 2024; Jiang et al., 2024a, 2024b), digital learning has made tremendous advancements in the past few decades, evolving from early online learning to a variety of learning modes today. It has profoundly transformed the ways of education and learning. Currently, learners can engage in learning anytime, anywhere through mobile devices like smartphones, tablets, accessing learning materials via mobile learning applications and interacting with teachers and peers. This convenience has made seamless learning possible. Blended learning combines traditional face-to-face teaching with online learning, creating a richer and more flexible learning experience. Students can interact in real-time with teachers and peers in the classroom while utilising online platforms for post-class exercises. This approach combines the strengths of in-person teaching with digital teaching and caters to diverse learning needs. Game-based learning integrates

game elements with educational content, sparking students' interest in learning. By participating in learning activities within games, students receive real-time feedback and more motivation to learn. Virtual reality and augmented reality learning allow learners to immerse themselves in various scenarios, providing an immersive learning experience and enhancing students' perceptual and comprehension abilities. In the future, digital learning will continue to reach new heights, empowering educational practices, providing more convenience for educators, creating positive learning environments for learners and nurturing more creative and curious students in society (Güzer and Caner, 2014).

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