Digital Educational Content of Technical Subjects: New AR and VR Technologies in Elementary School Teaching

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Abstract

In this article, we explore the potential use of digital educational content through augmented reality (AR) and virtual reality (VR) in teaching technical subjects at the upper primary level. Our research highlights innovative learning methods that enhance student interactivity and engagement, assist in visualizing complex projects, and provide opportunities for experimentation in a safe, simulated environment. The study also presents successful outcomes from schools that have integrated AR and VR into their educational objectives. We analyse the practical possibilities for implementing these technologies and discuss how they can help develop digital skills in schools and educational institutions, promoting good practices.

Keywords: Augmented Reality, Virtual Reality, Educational Technologies, Innovation

1 Introduction

Nowadays, technology significantly influences various aspects of daily life, including education. Traditional teaching methods are adapting to modern digital tools, enabling more effective and interactive learning experiences. The development of digital content brings a fresh perspective on acquiring and retaining knowledge, not only in primary and secondary education. Among the emerging technological trends are AR and VR, which will be discussed in detail in this article. Kesim et al. (2012) and Gavish et al. (2015) highlight Augmented Reality

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(AR) and Virtual Reality (VR) as interesting technologies with the potential to enhance the educational process through experiential learning in simulated environments.

AR allows users to interact with graphic elements, a text, and sound within the real-world environment, using smartphones or AR glasses. The potential of AR in education is vast, enabling students to engage with complex concepts in the classroom without the need for expensive equipment. Lee (2021) provides examples of AR's use in teaching technical subjects at the elementary schools, including interactive models and simulations of engines, machinery, and electrical circuits. These applications allow students to explore individual components in detail, understand their functions, and observe their interactions in real-time. Another practical example is the simulated assembly of circuits in a virtual laboratory, which eliminates the electrical hazard. The technologies required for using AR in the educational process include smartphones or tablets with cameras, as well as software and applications that process and display AR content.

Virtual Reality (VR) is a technology that provides a virtual environment, which users can experience through VR headsets. VR replaces the real-world environment with a simulated one. In education, VR enables students to engage in experiences that would otherwise be dangerous or inaccessible, such as simulated laboratory experiments or virtual field trips (Holdack et al., 2020). Virtual field trips allow students to visit manufacturing plants that are typically not accessible to students, providing them with practical experience and a better understanding of technical processes. Another example includes simulations of physical phenomena, where abstract concepts such as magnetic fields or wave propagation in space are visualized, helping students to grasp these concepts, which would otherwise be difficult to imagine without animated visual aids. These simulations take place in a safe and controlled environment (Gavish et al., 2015; Lee, 2021).

To achieve the best VR experience, the necessary technology includes a VR headset, motion sensors, and controllers that facilitate interaction with the virtual world, as well as software that creates and manages the virtual content (Greenwood & Wang, 2017; Smutny, 2023). AR and VR technologies hold great potential in education in today’s digitalized era. They offer new, engaging, safe, and experiential learning opportunities for students. AR adds digital elements to the real environment, while VR displays a fully virtual digital environment (Dembe, 2024).

2 The Importance and Application of AR and VR in Education

For several years, modern technologies have been integrated into the educational process, transforming traditional teaching methods. Educators strive to innovate teaching materials and adapt them to the contemporary era to make learning engaging and captivating for students. Digital technologies now play a crucial role in the educational process. VR and AR

technologies are among the key innovations that offer both students and teachers interactive engagement with educational content. These technologies allow students to explore the subject matter actively and experience interactions within a simulated environment, contributing to more effective achievement of educational goals while increasing student engagement and motivation (Dembe, 2024). Let us describe what both teachers and students can gain from the educational objectives supported by AR and VR technologies (Ghanbaripour, 2024):

- Experiential learning: Students engage in the learning process actively by manipulating virtual objects. This approach enhances their motivation, imagination, and engagement, while also allowing teachers to maintain students' attention.

- Safety in the educational process: Safety plays a crucial role in education. Through AR and VR, students can experiment and perform exercises safely without the risk of physical injury, damage to equipment, or material costs.

- Self-paced learning: Students can adjust the pace of their learning and training according to their individual needs. Applications can analyse students' progress and adjust the content to meet the performance and needs of both individuals and groups of students.

- Accessibility: Students have guaranteed access to education from anywhere, without the need for geographical relocation. They can participate in virtual field trips to locations they might not otherwise visit, such as laboratories or secure facilities that are off-limits to students.

- Practical skills development: Students acquire practical skills and experience with technologies that will be essential in their future professions.

- Inclusion: A key factor is inclusion, as VR and AR provide support for students with special needs, granting them access to the same educational experiences as other students.

In technical subjects and interdisciplinary contexts, studies and research focus on educational goals that employ Augmented Reality (AR) and Virtual Reality (VR). These technologies introduce innovative approaches that enhance interactivity and deepen students' understanding of technical concepts (Tan, 2022). In mathematics classes, AR can be utilized for the visualization and manipulation of three-dimensional geometric shapes. This teaching method allows students to comprehend better the volume and surface area of 3D shapes (Dunleavy, 2009; Bujak, 2013). During physics the lessons, students can experiment with the motion of objects under the influence of gravity using VR (Makransky, 2018).

In the field of electrotechnics, students can safely test electronic circuits in a virtual environment. Through experimentation, they acquire essential knowledge about electronic components and their capacity limitations (Psotka, 1995).

Robotics studies often necessitate expensive robotic arms for laboratory use, and careless handling could lead to injury or equipment damage. However, with virtual robotic laboratories, students can program and control virtual robots without risk, utilizing VR (Merchant, 2014). Students, under the guidance of their teacher, can visit manufacturing plants and technical workshops through virtual field trips without leaving the classroom (Pantelidis, 2010). AR and VR enable students to disassemble mechanical devices and gain a better understanding of their functionality (Dunleavy, 2009).

The use of AR and VR according to these examples not only increases student engagement and motivation but also fosters a deeper understanding of technical domains while providing a safe environment for experimentation without the need for expensive laboratories.

2.1 Strengths of Using AR and VR in the Educational Process

AR and VR introduce new possibilities into the educational process, significantly enriching traditional teaching methods. These technologies fundamentally transform how students receive information by engaging multiple senses. AR and VR can increase student interest by offering visual and auditory experiences through cutting-edge technologies. With VR, students can enter a digital world where they can explore various objects and scenes and interact with the environment through their activities. AR and VR allow students to complete interactive tasks, engaging them actively in the learning process. Students can solve problems using AR and VR, an approach known as problem-based learning, where students can be tested, rewarded, and assessed in a fun and motivating way based on their memorized and practiced knowledge. By completing tasks, students demonstrate their practical skills.

Technological advancements enable students to work in groups in virtual environments where they can communicate and collaborate as a team. Teachers can organize virtual meetings where students discuss, study, and learn in real time within the virtual space. AR and VR technologies enable the visualization of complex technical concepts, making them easier to understand by presenting them as complex 3D structures that students can rotate, tilt, and examine from different angles. These technologies also allow for the creation of animations that guide students through dynamic processes, such as chemical reactions or the functioning mechanisms of machines and devices in a safe environment. Before operating real machinery, students can test and verify these processes in a virtual setting, ensuring they have acquired the necessary knowledge and training to handle real-life situations safely. This is particularly important when real-world experiments could be dangerous and life-threatening (Georgy, 2016).

Training through AR and VR includes practicing medical procedures, repairing machines and devices, assembly techniques, and rescue operations during earthquakes. Properly designed applications can save lives, reduce material damage, and prevent losses that could occur due

to unskilled or untrained procedures. The interactive elements of AR and VR provide immediate feedback, helping students quickly identify and correct errors, allowing them to proceed with the correct approach (Ong, 2013). These technologies have the potential to transform educational goals in technical subjects and improve students' learning outcomes.

2.2 Weaknesses of Using AR and VR within the Educational Process

Despite the numerous advantages that AR and VR bring to education, there are challenges and limitations associated with their implementation in the educational process. One of the primary concerns is the high acquisition cost of these technologies. VR headsets, AR glasses, and the development of applications for technical subjects can represent significant financial burdens for schools. Additionally, it is crucial to continuous update the content of these applications to ensure relevance. VR applications often demand high hardware specifications for the computers to which the VR headsets are connected (Radianti, 2020).

From a health perspective, prolonged use of VR headsets can lead to eye strain, dizziness, and headaches. Users may also risk physical accidents, such as bumping into walls or tripping over objects that are not visible in the virtual world (Samala, 2023).

Another challenge is the need for teachers to be adequately trained to use these technologies effectively. Teachers must possess solid technical knowledge to integrate AR and VR into their teaching. Additionally, educational content may not always be sufficient for every subject, necessitating continuous updates and enhancements. Excessive use of AR and VR might lead to the erosion of traditional skills, such as handwriting, reading from text, and personal communication. Therefore, when planning lessons, it is essential to complement AR and VR with more traditional teaching methods (Bower, 2014).

Another critical aspect is the ethical considerations surrounding the use of AR and VR. Users must be aware of how sensitive student data, including biometric information, are collected, stored, and handled. It is also crucial to ensure that the didactic content presented to students is properly controlled (Falkner, 2020).

These mentioned weaknesses highlight the challenges that must be carefully considered when introducing new technologies into the educational process.

2.3 Steps for Implementing VR and AR into the Educational Process

The implementation of VR and AR into education requires thorough planning and clearly defined steps. To achieve effective results, it is essential to start by identifying the educational needs and areas where AR and VR technologies can offer significant benefits. After identifying these areas, the next steps involve selecting appropriate tools, preparing technical infrastructure, and training educators. First, define the primary objective to be achieved through the use of VR or AR technology. For example, a goal could be: "Provide students with practical and interactive assignments using AR technology, where students learn about electronic components, understand their functions, and their integration in real circuits." Sub-

goals might include: "Allow students to visually explore electronic components with descriptions," and "Demonstrate circuit configuration simulations using AR, enabling students to experiment with circuit modifications." Next, appropriate hardware and software must be selected, ensuring they meet current recommendations, fit within the budget, and are versatile enough to be used across various subjects and topics. In the case of AR, devices such as tablets, smartphones, or AR glasses can be used. Educational content that aligns with the lesson objectives should either be sourced from existing material or developed using specialized applications such as Unreal Engine or Unity, though these platforms may require programming skills. Once the desired educational content has been located, synchronized with the hardware, and tested, the implementation of AR technology into the curriculum can begin. After introducing AR into the classroom, it is critical to gather feedback from students to assess the effectiveness of the approach and refine future lessons based on their suggestions.

If the AR integration proves successful, the knowledge gained can be shared with the broader school community. Teachers can present their experiences to colleagues, plan, and conduct training sessions for educators who will use AR technology in their teaching practices.

3 Examples of good practice

Examples of good practice in implementing VR and AR into the educational process demonstrate how effectively these technologies can enrich instruction. Their use introduces innovative teaching methods that increase student interest and promote active engagement in learning, facilitating the acquisition of theoretical knowledge and practical skills. Let us examine specific cases where AR and VR have shown significant potential in the educational process.

Studies highlight the benefits of these technologies in educational settings. In the subject of physics, AR technology has proven to be an effective tool for explaining complex physical phenomena. In a study conducted by Volioti (2022) involving fifth and sixth-grade students, it was confirmed that students were better able to comprehend physical concepts such as units of weight, forms of energy, heat and temperature, and the passage of light through various materials. Through gamification, students learn in a playful manner, which is engaging and allows teachers to appreciate the integration of AR into their teaching practices.

Moreover, AR provides students with experiences that would otherwise be challenging or impossible to obtain through traditional teaching methods. For example, observing physical phenomena in real-time and in 3D space helps to forge stronger connections between theory and practice. It is equally important that teachers value the integration of AR into their instruction, suggesting that this technology can effectively complement existing educational methods. However, this raises the question: “Is this approach suitable for all age groups of students, and is the availability of technology in schools sufficient?” A similar perspective on AR in the context of physics is presented in the study by Cai et al. (2020).

The authors analysed the impact of AR on students' self-efficacy in learning physics through the examination of the photoelectric effect. The research results indicate that the appropriate incorporation of AR into teaching contributes to improved understanding and the ability to apply acquired knowledge. Comparing this to previous studies, it can be observed that in addition to increased motivation, AR also has psychological effects on students, helping to enhance their confidence in solving physics problems and abstractly presenting commonly invisible physical phenomena. Furthermore, it would be beneficial to explore the long-term effects of using AR on knowledge acquisition. The suitability of AR for mastering geometric content is evidenced by the study conducted by Pradibta et al. (2023).

Students who utilized AR for visualizing geometric shapes demonstrated improved results in understanding spatial relationships, with as many as 92.8% rating this approach positively. In comparison to physics, it is evident that in mathematics, the visual aspect of AR plays a crucial role. The interactivity that AR offers enables students to grasp spatial relationships and geometric objects more effectively. This element is often lacking in traditional lessons that do not incorporate new information and communication technologies (ICT), making AR a valuable complement in teaching subjects that emphasize abstraction. From our perspective, AR provides students with opportunities to actively explore and experiment, thereby enhancing their engagement and fostering creative thinking. However, discussions should address how to ensure equitable access to this technology across all schools, so that it can become a standard component of education rather than just an adjunct at selected institutions. In the field of chemistry, Hoai et al. (2024) investigate how the use of simulated AR videos aids students in better understanding chemical processes, such as chemical bonding.

Students were able to apply the knowledge gained more effectively in problem-solving tasks, suggesting that AR can be a significant tool for enhancing cognitive abilities in chemistry. In chemistry, AR focuses on simulating processes that are otherwise difficult to visualize. Comparing this study to other science subjects like physics and geometry, it is clear that AR in chemistry emphasizes the representation of invisible, microscopic processes, allowing students to work with dynamic models that would otherwise remain abstract. Similarly, AR provides an interactive and visual approach, facilitating a deeper understanding of complex concepts and promoting inquiry-based learning.

A study by Porus (2023) examining the integration of VR in teaching 3D programming languages in elementary schools indicates that VR enhances creativity and student engagement, thereby facilitating the comprehension of complex programming concepts. This approach is considerably more immersive than AR, as VR provides full immersion in a digital environment, enabling students to directly interact with code in 3D space. From this perspective, it can be concluded that VR is an ideal tool for teaching disciplines that require a high level of interaction and creativity. By providing students with a space for exploration and creation within a fully interactive environment, VR significantly boosts motivation and engagement in the learning process. The question remains as to how VR can be effectively

integrated into school curriculum to ensure it is accessible and beneficial for all students, especially given the technical and financial demands of this technology.

Xie et al. (2022) suggest that simulations of specific instructional components help students more easily understand abstract concepts and mathematical models. This learning approach enables students to better connect theory with practice, which is crucial, particularly in subjects characterized by a high degree of abstraction, such as mathematics.

Based on the analysed studies, we can conclude that AR and VR technologies bring significant improvements to the educational process in specific subjects at both elementary and secondary schools. Our findings indicate that appropriately selected technologies, coupled with expert lesson management, enhance student engagement, increase comprehension of the material, and improve motivation, creativity, and abstract thinking while providing new interactive learning opportunities. However, when implementing AR and VR in the educational process, it is essential to consider the technical and financial requirements to ensure accessibility for all students.

4 Conclusion

The future of AR and VR in technical education at the elementary level holds significant potential. By utilizing AR and VR in elementary subjects, we can profoundly change the way students learn, enhancing their imagination, comprehension of the curriculum, and interest in education and training. For the successful implementation of these new technologies, it is essential to focus on developing the technical infrastructure of schools, training educators, and securing financial resources for the acquisition of hardware and software.

With increasing availability and technological advancements, AR and VR have the potential to substantially improve the educational process and prepare students for real-world applications. Innovations in education are crucial for equipping students for careers in various industries and organizations. By seeking new and effective teaching methods such as AR and VR, we can ensure an elevation in educational standards that responds to the changing needs of society. The landscape of education is undoubtedly evolving in alignment with technological progress. AR and VR technologies represent significant tools that can fundamentally transform the learning environment and contribute to a deeper understanding of complex topics. When teachers and students become familiar with these technologies and begin to utilize them in achieving educational objectives, they will open new avenues that enrich the educational process and provide students with opportunities for practical learning.

Integrating AR and VR into technical education supports the development of key competencies in education, such as critical thinking, creativity, and technical skills that will be essential for students seeking employment. However, despite the substantial benefits, there are weaknesses, including the high costs associated with AR and VR technologies, the need for specific hardware and software, and the time and resources required for the professional training of educators. Moreover, there is a risk that improper use of these technologies in the

educational process may distract students from core curriculum content if not appropriately integrated into pedagogical approaches. If schools and educators can effectively implement AR and VR in their teaching practices, they can enhance the quality of education and prepare students for future careers. Thus, AR and VR represent a significant shift in the educational landscape once the weaknesses associated with these technologies are addressed.

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