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THE USE OF AR/VR TECHNOLOGIES IN DEVELOPING STUDENTS' DIGITAL COMPETENCIES

Introduction

In the modern educational landscape, the development of students' digital competencies is of particular importance, as it determines their level of professional readiness, adaptability to rapid technological changes, and competitiveness in the labor market. The growing role of digital technologies in various fields of human activity necessitates the adoption of innovative teaching approaches capable of providing students with access to interactive digital environments, modern tools for working with information, and a high level of practical training. The development of technologies such as artificial intelligence, cloud computing, automation, big data, and the Internet of Things requires a transition to modernized models of learning based on immersive and visually rich digital platforms.

In this context, augmented reality (AR) and virtual reality (VR) technologies play a special role, as they significantly enhance the didactic potential of academic disciplines, making the learning process more interactive, engaging, and practice-oriented. AR/VR technologies enable the creation of high-immersion learning environments in which students not only observe processes but also interact with them actively. Thanks to AR/VR, it becomes possible to reproduce complex technical systems, model various professional situations, create simulations of real working conditions, and conduct experiments without the risks inherent in real-world settings. This forms a new pedagogical paradigm in which learning through action, exploration, and experimentation becomes the foundation for developing competencies.

The relevance of AR/VR technologies is reinforced by the results of modern educational programs and initiatives, particularly the IMPACT Campus Training Week course, dedicated to the development of digital skills, inclusive

approaches, automation, and the adaptation of innovative technologies to educational processes. This program emphasizes digital transformation in education, the potential of artificial intelligence, and the use of digital tools to support students, optimize teaching practices, and improve instructional quality. All these factors create a foundation for integrating AR/VR into the training of future specialists.

The need to implement AR/VR in the learning process arises from the fact that traditional teaching methods do not always provide sufficient immersion in the subject matter, especially when dealing with disciplines that involve complex technical processes, the visualization of abstract concepts, or the modeling of professional scenarios. AR/VR allows students to immerse themselves in virtual environments that reproduce real or imagined spaces, enabling interaction with models and objects which significantly enhances understanding. For fields such as engineering, medicine, computer science, architecture, design, and natural sciences, these technologies can become indispensable tools that greatly expand learning opportunities.

AR/VR as a Tool for Developing Students' Digital Competencies

The use of AR and VR technologies in education contributes to the development of a wide range of digital competencies defined by the European Digital Competence Framework (DigComp) and Ukrainian standards for digital education. One of the key competencies is information and digital literacy. AR/VR provides an environment where students work with digital objects, 3D models, simulations, educational datasets, and results of virtual experiments. This fosters skills in analyzing information, searching, interpreting, and critically evaluating digital data. Working with AR/VR requires operating with large amounts of visual information, which helps students better understand complex concepts and apply knowledge to practical tasks.

Another important competence is interaction with digital technologies. AR/VR environments differ from traditional digital platforms by their three-dimensional structure, spatial organization, and specific modes of interaction. Students learn to navigate virtual space, use controllers, interact with gestures, and adapt to interfaces that require different types of thinking and motor skills. This develops essential abilities for working with modern 3D systems, modelling

tools, robotics, simulators, and other technologies that are becoming increasingly common in professional contexts.

A particularly valuable competence developed through AR/VR is visualisation and spatial reasoning. In many fields, students must understand structures, systems, algorithms, and processes that are difficult to imagine in two-dimensional form. AR/VR enables the recognition, analysis, and transformation of objects in three-dimensional space. For example, students can examine cell structures, internal device components, complex chemical models, architectural constructs, or computer science algorithms through interactive 3D visualisations. This fosters deeper understanding and strengthens the ability to apply knowledge in real-world professional contexts.

Digital communication and collaboration is another essential competence enhanced through AR/VR. Virtual environments may incorporate group simulations, shared VR classrooms, and real-time collaboration, allowing students to engage in team-based tasks. This is particularly useful for disciplines requiring cooperative problem-solving or collective project work. Such formats cultivate communication skills, teamwork abilities, role distribution, and strategic thinking.

AR/VR also strengthens digital creativity and content creation skills. In environments such as CoSpaces Edu, Unity, Blender, Unreal Engine, and WebXR, students can design immersive scenes, models, educational simulations, AR applications, and VR spaces. This fosters competence in programming, 3D modelling, design, and UX/UI development, all of which are highly demanded in many professional fields.

Thus, AR/VR technologies function not only as tools for visualisation but as comprehensive platforms for developing modern digital competencies, enabling students to work with innovative technologies, think spatially, interact with digital systems, and create new digital content.

Pedagogical Opportunities and Advantages of AR/VR in Education

Immersive technologies open new pedagogical opportunities by enhancing the effectiveness of the learning process. One of the key benefits is the increase in student motivation and engagement. Research demonstrates that visualisation and immersion improve knowledge retention and facilitate deeper understanding. Students perceive learning in VR or AR as a more

interactive and engaging process, encouraging active participation and independent inquiry.

AR/VR technologies create safe environments for simulating complex or hazardous scenarios. VR can model chemical reactions, surgical procedures, mechanical system operations, electrical work, or emergency response situations without the risks associated with real-world settings. This allows students to practise diverse professional tasks and gain experience that cannot be achieved with traditional teaching methods.

AR/VR supports personalised learning. Virtual environments can be adapted to individual student needs, allowing for adjustments in complexity, pace, and repetition of simulations. This enables personalised learning trajectories, which is particularly valuable for students with diverse backgrounds and learning speeds.

Immersive technologies also support practice-oriented learning. In VR, students can assemble mechanisms, study structures, conduct experiments, and interact with virtual objects in dynamic settings. AR overlays digital content onto the real world, expanding opportunities for laboratory work, demonstrations, and hands-on activities.

In natural sciences, medicine, engineering, and creative disciplines, AR/VR enhances the comprehension of complex concepts by visualising objects that cannot be reproduced in real life. Medical students can explore anatomical structures, perform virtual surgeries, and practise diagnostics. Engineering students can test designs, study physical processes, and work with 3D models. In the arts, students can create virtual galleries, animations, and interactive environments.

Thus, the pedagogical potential of AR/VR encompasses a wide range of opportunities—from increasing motivation and learning efficiency to supporting innovative approaches for developing practical skills, critical thinking, and digital culture.

Examples of AR/VR Applications in Computer Science

In computer science, AR/VR technologies offer possibilities for visualising complex algorithms, architectures, and systems. Students can model sorting algorithms, search algorithms, decision trees, and graphs in three-dimensional

space, observing algorithmic behaviour in real time. This improves understanding of logic, data structures, and system interactions.

VR laboratories allow students to “step inside” a computer to explore processor architecture, cache memory, data-transfer buses, and operating system structures. This simplifies the comprehension of concepts that are traditionally abstract.

In networking courses, AR/VR enables the modelling of routers, switches, virtual networks, and real-time packet flow. Students can explore network operations without the risks associated with working on real hardware.

In cybersecurity, VR is used to simulate cyberattacks, analyse vulnerabilities, and train incident-response strategies. This allows students to experience realistic threat environments in safe conditions.

AR is widely applied in robotics and IoT courses. Students can program robots, analyse sensor behaviour, test navigation algorithms, and visualise code structure in 3D. This enhances understanding of embedded systems and autonomous agents.

VR is also used in artificial intelligence research, including reinforcement learning, synthetic data generation, and agent-based simulations. VR hackathons, collaborative coding environments, and virtual engineering spaces are becoming increasingly common.

Thus, AR/VR technologies are transforming computer science education, making it more practical, immersive, and technologically aligned with modern industry requirements.

Challenges and Limitations of AR/VR Implementation

Despite the significant potential of AR/VR technologies, several challenges hinder their widespread adoption. Technical barriers include the high cost of equipment, the need for powerful computers or smartphones, stable internet connectivity, and continuous software updates. Content development for AR/VR is also costly, requiring expertise in 3D modelling, programming, and design.

Pedagogical challenges include the need for teacher training, curriculum adaptation, development of immersive scenarios, and effective classroom management within AR/VR environments. Insufficient digital literacy among instructors may reduce the effectiveness of AR/VR integration.

Health and safety concerns include eyestrain, motion sickness, balance issues, and the collection of sensitive biometric data. Some AR/VR systems may be inaccessible to students with visual impairments or physical limitations.

Content-related issues include a lack of high-quality educational materials in local languages, limited interoperability between platforms, and insufficient alignment with specific academic curricula.

Future Prospects

The future of AR/VR in education is linked to the development of mixed reality (MR) and the emergence of educational metaverses—comprehensive virtual spaces for learning, collaboration, experimentation, and project work. Integration with artificial intelligence will enable adaptive learning scenarios, automated content creation, and advanced analytics. In the coming years, AR/VR technologies are expected to become a standard component of professional training in many fields.

Conclusions

AR/VR technologies are powerful tools for developing students' digital competencies and improving the quality of education. They provide immersive environments that enhance practical learning, enable the modelling of complex processes, support personalised learning, and foster the development of essential modern skills. However, their effective implementation requires investment, pedagogical preparation, and methodical support. The continued evolution of AR/VR, combined with artificial intelligence, will contribute to the formation of a new educational paradigm focused on innovation, adaptability, and deep practical learning.