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VIRTUAL REALITY INTEGRATION IN THE FUNCTION OF HYBRID-IMMERSIVE EDUCATION

Abstract: The introduction of virtual reality as an instructional technology enhances the educational potential of hybrid teaching due to its immersive component, which enables a more comprehensive experiential learning experience. The subject of this research is the systematization and analysis of existing technical, content-related, and pedagogical knowledge on the purposeful integration of virtual reality into educational environments, with the aim of defining methodological and pedagogical foundations for the development of a prospective hybrid-immersive teaching model. The results of a comparative analysis of ten scientific case studies indicate that diverse hardware sets are utilised across various teaching domains at all three levels of education. Ten pedagogical learning theories have been identified as foundational for the implementation of innovative educational activities involving virtual reality technology. Key methodological constructs and stages of a hybrid-immersive instructional model have been defined using the modelling method and includes four phases: adaptation, exploration, collaboration and experience exchange, evaluation.

Keywords: virtual reality, immersion, hybrid learning environment, experiential learning, educational technology

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INTRODUCTION

Educational challenges raise questions about how the rapid development of intelligent technology will influence the learning process and how learning environments should be structured to foster individuals competent for life and work in the near future. One promising response that contemporary education can rely on is the integrated connection between emerging teaching models and the potential of state-of-the-art technology.

For educators designing instructional activities, it is important to consider that immersive technology enables virtual content to be experienced as real. Sensory exposure to specific external stimuli is required to create a sense of presence within an artificially generated environment. The medium enabling this immersive experience is virtual reality (VR) technology, which allows content to be experienced through simulated scenarios in controlled learning environments, engaging both the emotional and intellectual aspects of personality development.

While VR will not revolutionise education, it is believed to offer a valuable and entirely new dimension to pedagogical research (Kaser et al, 2019). Integrating technology into teaching requires careful didactic-methodological planning and consideration of how solutions can enhance learning outcomes. Emphasis is on methodical models for VR integration, highlighting the importance of creative teaching approaches. Teachers should use technology to improve content comprehension and maximise individual development (Legi et al, 2022).

Various applications of modern educational technology are continuously being explored to support the development of teaching models such as blended and hybrid learning, which integrate traditional face-to-face instruction with e-learning with the aim of creating a more stimulating environment for learning and personal growth (Ristić & Mandić, 2018). Additionally, artificial intelligence (AI)-based tools can support virtual collaboration, enabling students to cooperate beyond the confines of the physical classroom (Mandić, 2024).

In this context, this research focuses on VR from the perspective of educational technology, particularly its potential to enhance and support the development of hybrid learning environments where students will have fundamentally different learning experiences.

METHOD

The subject of this research is the systematization and analysis of existing technical, content-related, and pedagogical knowledge on the purposeful integration of virtual reality into educational environments, with the aim of defining methodological and pedagogical foundations for the development of a prospective hybrid-immersive teaching model. Based on this aim, three research tasks were defined:

1. To identify scientific studies that meet the criteria of diversity in terms of hardware characteristics of VR technology, content (in various fields of application and different levels of education), and different pedagogical learning theories in basic methodological frameworks;
2. To determine how VR technology is used for educational purposes from the perspective of technical, content-related, and pedagogical subsystems;

3. To define the methodological constructs and phases of the hybrid-immersive teaching model.

The sample includes ten case studies published after 2016, as these years marked significant investments by companies such as Facebook and Samsung in the development of graphics for immersive virtual environments, as well as the production of affordable hardware such as Google Cardboard, Oculus Rift, and HTC Vive. This also led to a substantial increase in published research, particularly in the field of education, starting from 2017 and 2018 (Rojas-Sánchez et al, 2023).

Two methods were used in the paper: comparative analysis and the modeling method. Considering the complexity of the process of integrating VR technology into educational settings and guided by the “Pedagogical Framework for Designing Immersive Teaching Environments” (J. Ristić, 2022), a comparative analysis of ten scientific case studies was conducted through research activities detecting three interdependent subsystems. The content analysis units within the technical subsystem focused on the most common hardware and software solutions. Within the other two subsystems, different pedagogical learning theories were identified that can provide a foundation for the integration of VR technology in various content areas and levels of education. Finally, a modelling method was applied to define the methodological constructs and phases of the hybrid-immersive teaching model.

RESULTS AND DISCUSSION

From the educational technology perspective, for VR to contribute to the maximum achievement of pedagogical goals and effectively support the implementation of specific educational content, its technical capabilities must be analysed. In this regard, the technical subsystem will be described first, followed by the content-related and pedagogical subsystems, referring to the analysed data from Table 1.

Technical Subsystem

It is well established that the quality of hardware and software partly determines the success of VR technology integration in education (Howard, 2019). Within the technical subsystem, it is suggested that the selection of VR hardware and software should be based on the psychological and physical characteristics of students (J. Ristić, 2022), as well as careful consideration of the degree of immersion and interactivity.

Immersion ensures that the VR user experiences the illusion of presence in a realistic environment. The level of immersion and the intensity of perceiving a given environment as real depend on hardware performance, which ensures the authenticity of the display, as well as the ability of the user to interact with virtual entities.

Analysis of the technical subsystem in the sampled case studies revealed that two categories of VR hardware are equally represented: “mobile VR and interactive 3D VR” (Kaser et al, 2019, pp. 50). Mobile VR, such as Google Cardboard, Samsung GearVR (Choi et al, 2018; Bhattacharjee et al, 2018; Makransky et al, 2019; Jong et al, 2020; Watthanapas et al, 2023), essentially consists of glasses with

specialised lenses onto which the mobile phone screen is mounted. This concept of artificial hardware extension indicates a limited field of view and reduced resolution when producing video content in a 360-degree format. It does not provide a complete sensory immersion experience into virtual content due to the limited ability to make choices and interact with the virtual environment. Nevertheless, it is considered a good starting solution, not only because of its affordable price but also due to the possibility of applying mobile learning in hybrid teaching, supported by various mobile devices, applications, and web tools (Ristić & Mandić, 2018).

Interactive 3D VR, such as HTC Vive, VR goggles, Oculus/Meta Quest, Oculus Rift (Babu et al. 2018; Chang et al. 2020; Feng et al. 2021; Kennedy et al. 2023; Markwell et al. 2023), features significantly better-designed hardware components. The VR headsets, with exceptional graphic performance, integrated headphones, and special controllers for both hands, ensure that users experience physical movement simulations in virtual space. Unlike mobile VR, users of interactive 3D VR can manipulate virtual content by moving objects with controllers. This allows them to make various decisions, perform multiple choices, and interact with the virtual environment at a much higher level (e.g., with a virtual avatar).

Regardless of the level of immersion and interactivity of VR technology, all studies except one (Markwell et al, 2023) have proven that the experimental group using immersive environments performed better than the control group, which used traditional content presentation methods (from printed media or multimedia).

Regarding the software aspect, the IT industry predominantly creates software packages with VR content, most of which are commercially entertainment-oriented (Ristić et al, 2023). Therefore, numerous references (Kaser et al, 2019; Jong et al, 2020) emphasise the need to specifically define a framework for designing VR content intended for learning purposes. In the analysed studies, the participants used some of the available online software packages, such as Franklin's Lab, EduVenture-VR, Arterial Blood Gas (Vantari VR), Cloudlands VR Minigolf. However, some studies (Choi et al, 2018; Babu et al, 2018; Feng et al, 2021) indicate that, at times, it is necessary to specifically design content for certain learning situations, for which the Unity3D engine platform is most commonly used for video game development.

CONTENT-RELATED SUBSYSTEM

As shown in Table 1, studies are represented at all educational levels, with the most representation in higher education. Illustrations 1-10 show graphic representations of the virtual environments of the software that were integral parts of the experimental programs in the analysed studies.

In the first study (Choi et al, 2018) on Illustration 1, three scenarios were used for learning biology through games. The first provided information about marine biodiversity, after which the participants played two fishing games from different positions, earning points and gaining additional information about the specifics of fish.

The results of the second study (Babu et al, 2018) highlight VR as a bridge between theory and practice in engineering at the university level. The experimental group in the immersive 3D environment

(Illustration 2) demonstrated significantly better declarative and procedural knowledge about engine structures compared to the group that learned using 2D content on a tablet.

The third study (Bhattacharjee et al, 2018) emphasises the importance of connecting chemistry and biology to understanding the function of DNA (Illustration 3). Students without developmental difficulties and those with Attention Deficit Hyperactivity Disorder (ADHD) and Audio Processing Disorder (APD) participated in the study. The VR experimental groups were better than the control groups in knowledge retention, creativity, and practical application.

The experimental group in the fourth study (Chang et al, 2020) significantly outperformed the control group in innovative thinking about the ideal design of a toy car. By using VR, they received more visual stimuli (Illustration 4), and through personal experience, their reflective observation and abstract conceptualisation were enhanced.

In the fifth study (Makransky et al, 2019), VR was applied to investigate the sense of authenticity and presence of a virtual avatar in solving STEM scientific problems through social interaction. The initial hypothesis was confirmed that girls would identify more with an avatar resembling a girl of their age (Illustration 5 - right), while boys would identify more with a flying robot (Illustration 5 - left).

The sixth study (Watthanapas et al, 2023) investigated a multilingual VR system for learning the Thai language (Illustration 6). The VR environment encouraged the repetition of cognitive processes, movement coordination, and reduction of anxiety during learning.

The quasi-experimental study (Jong et al, 2020) investigated geography teaching on coastal processes. Students in VR scenarios (Illustration 7) achieved better results on the test compared to the control group, which learned through traditional methods.

In the eighth study (Kennedy et al, 2023), medical students used the VR software Arterial Blood Gas to simulate an operating room environment with the aim of developing procedural skills for blood sample extraction on a virtual patient (Illustration 8). Self-reflection was facilitated through haptic feedback via the intensity of pulsing vibrations in the handheld controller.

Through a virtual earthquake simulation in an enclosed space (Illustration 9), children from the experimental group in the study by Feng et al. (2021) gained procedural knowledge about implementing safety measures and evacuation, with an exceptionally high level of self-efficacy.

The virtual sports environment in Illustration 10 represents experiences that are approximately similar to real-world training environments (Kim et al, 2019). This is confirmed by the last study (Markwell et al, 2023), with results from the experimental group showing very similar improvements in motor skills related to accuracy and technique of golf club swings compared to the control group.

Pedagogical Subsystem

A review of meta-analyses reveals that the technical and content-related subsystems are most commonly addressed, while the pedagogical subsystem in the domain of learning theories is not always explicitly stated (Radianti et al, 2020; Hamilton et al, 2021; Scavarelli et al, 2021). For an educational tool to reach its full potential in a specific educational context, it must be based on a relevant pedagogical theory or educational paradigm. This approach helps identify the most suitable pedagogical

framework for implementing the technology, ensuring the selection of the most effective teaching methods (Hamilton et al, 2021).

Table 1 presents 10 different learning theories that researchers have referred to in the context of learning and training at the primary, secondary, and higher education levels. Given that “the constructivist paradigm encompasses a heterogeneous set of theoretical approaches” (Ćirić & Jovanović, 2018, pp. 60) the analysis indicates that most learning theories stem from the constructivist paradigm, which is based on the idea that only through personal experience and active participation in physical and social environments can an individual “construct” unique knowledge and develop specific skills (Huang et al, 2010).

The results of the study by Choi et al. (2018) show that VR stimulates play-based learning, which, through interactions in an immersive environment, is tailored to the individual needs of students. Students actively apply knowledge by collecting points, making decisions, and receiving feedback on the correctness of their choices.

VR with immersion functions can provide a good level of realism and interactivity, which are necessary prerequisites for situated learning (Huang et al, 2010). The outcomes of situated learning in VR are reflected in the functional transfer of knowledge and procedural skills (acquired during virtual training) to new realistic situations, as confirmed by another study (Babu et al, 2018).

Student engagement is a key concept in understanding the theory of learning by doing. The level of student engagement depends on the level of interactivity with the VR system, sensory information, as well as the content within the virtual environment (Bhattacharjee et al, 2018). The VR system constantly generates information and provides a personalised simulation according to the individual work pace, along with the modification of the environment (Bhattacharjee et al, 2018).

The study by Chang et al. (2020) explored the effects of VR on the processes of creative experiential learning. Participants were guided to reflectively observe a virtual model of a toy car and engage in abstract conceptualisation, which further initiated active experimentation and stimulated innovation. The results suggest that VR technology significantly enhanced the entire creative design process and promoted design thinking.

Virtual environments provide an opportunity for realistically depicting avatars as assistants in the learning process, which can be designed according to the pedagogical principles of social-cognitive learning theory. Research (Makransky et al, 2019) has shown that there is a higher level of identification when the virtual avatar is more similar to the student (in terms of gender, skin colour, age, cultural appearance, etc.), leading to higher levels of self-engagement, interaction, and motivation, as well as better learning outcomes.

The study by Watthanapas et al. (2023) explored the effectiveness of using a VR system in foreign language learning, focusing on practising word order by combining the Theory of Embodied Cognition and the Cognitive Theory of Multimedia Learning (CTML). Embodied cognition emphasises learning through physical interaction with the environment (Schneegans & Schöner, 2008), while multimedia learning integrates words, images, and motion (Watthanapas et al, 2023). The results show a positive impact on students’ cognitive and affective states, improving learning outcomes and knowledge retention. This aligns with the potential of modern information technology to integrate all stimuli influencing an individual’s mental and emotional state (Nikolić et al, 2020).

The study by Jong et al. (2020) was based on the inquiry-based learning theory, which emphasises student engagement in exploring geographical phenomena. The pedagogical model tested was the Learner-Immersed Virtual Interactive Expedition (LIVIE), incorporating Dewey's experiential learning theory and Vygotsky's Zone of Proximal Development (Jong et al, 2020). The framework, consisting of five phases—Communication, Orientation, Exploration, Explanation, and Reflection—integrated traditional teaching with VR-based experiential learning. The results showed that LIVIE had a positive impact on students across all achievement levels.

The study by Kennedy et al. (2023) investigated the trial-and-error learning theory in the process of teaching medical students. The VR system detected mistakes during blood sample collection on a virtual patient and provided feedback, resulting in 40% fewer mistakes in real-life conditions and greater expertise for future doctors. The authors emphasise that making mistakes in a safe simulated environment is a key part of the learning process, enabling an understanding of the consequences (Kennedy et al, 2023).

The study by Feng et al. (2021) explored a framework for developing digital games grounded in problem-based learning theory through VR training to prepare for natural disasters such as earthquakes. Solving problem situations in VR, along with analysing the decisions made, proved to be significantly more effective in acquiring procedural knowledge and self-efficacy compared to traditional learning from printed media.

The theory of transfer learning was the basis of the study by Markwell et al. (2023), which demonstrated that VR environments stimulate the activation of cognitive structures and support the development of sports skills. The study further showed that students could practically apply the skills acquired in VR to real-life situations in a real-world environment.

The analysis of the content of virtual scenarios revealed the key potentials of VR that contribute to the “continuously developing competencies for lifelong learning” (Mandić et al, 2024, pp. 371) as well as supporting various learning styles and teaching models (M. Ristić, 2019).

HYBRID-IMMERSIVE TEACHING MODEL

The current educational approaches will be insufficient to meet the evolving needs of education (Dumančić, 2019). The gap in learning and practice in real environments such as schools can only be partially eliminated through the use of virtual simulations and AI programs (Šuvaković et al, 2022). Therefore, the hybrid teaching environment can be an excellent solution as it involves a planned, continuous, and integrated set of educational activities (Marjanović & Veljković, 2022). It fosters greater sensitivity to students' needs, enhances interactivity, and improves learning effectiveness (Ristić et al., 2022), emerging from the integration of the best elements of both traditional and online models.

It is important to emphasise that the terms Blended learning and Hybrid learning are often used as synonyms because they include a combination of in-person instruction (Astuti et al, 2019) and computer-mediated instruction (O'Byrne & Pytash, 2015). However, the primary difference lies in their structure: blended learning integrates both eLearning and traditional classroom instruction, requiring a combination of both methods, while hybrid learning provides students with the flexibility to choose between attending classes in person or engaging online (Neelakandan, 2021).

Methodologically speaking, VR technology has the potential to create an online environment that can stimulate Structured Enactive Engagement in Learning (SEEL) with the tendency to initiate the connection between the cognitive and psychomotor domains through specific virtual experiences (Punako, 2018).

The analysis of various learning theories served as the basis for defining the pedagogical subsystem of the hybrid-immersive teaching model (Scheme 1). Considering that the constructivist approach was the most prevalent, an instructional design based on the theory of Computer-supported Collaborative Learning (CSCL) has been proposed, which rests on the symbiosis of technology and learning guided by holistic and constructivist principles.

The core concept of the hybrid-immersive teaching model with VR technology is based on strengthening the connections between the cognitive, affective, and psychomotor domains of individual personality development in the learning process through active participation and independent decision-making.

The goal is to provide stimulating incentives to strengthen the connections between experiences from experiential learning and cognitive processes, i.e., the conceptualization that organises the ideas gained through experience and the understanding of what has been observed in the virtual environment. In this regard, in such a model, active observation is directly linked to concrete action (experimentation). Chang et al. (2020) emphasise the importance of these constructs, which work synergistically to build knowledge or develop specific skills that will be used for innovative and functional applications.

The technical subsystem of the hybrid-immersive teaching model consists of a specialised educational platform and VR technology. The educational platform is used in two ways: as support for in-person teaching at schools or universities, for uploading instructional materials, tasks, and guidelines for completing assignments, as well as for providing conditions for engaging online (eLearning). VR headsets with controllers are used to simulate specific teaching content and interactive tasks. In such an environment, learning is organised through precisely structured tasks with role assignments, aiming for students to collaboratively work on problem-solving, engage in hypothetical reasoning, share experiences, distribute information explore, check evidence, and ultimately engage in reasoned communication (Punako, 2018) and draw conclusions.

It is recommended that the content-related subsystem of this model be integrative in nature – abstract, temporally and spatially distant, and focused on solving specific problem situations. This could also include content for which a secure learning environment must be provided for exploration (J. Ristić, 2022).

Based on all the aforementioned, four phases of the hybrid-immersive teaching model have been defined, expanding the existing three-phase model for the integration of VR in education (Ristić et al, 2023), which consists of adaptive, immersive, and reflective periods.

1) The first phase (adaptation): This phase covers the introduction to the teaching topic and preparation for learning in a hybrid-immersive environment. The research problem is presented live/online in such a way that students cannot solve it individually (Punako, 2018). Training is provided on using the educational platform, and the proper use of VR hardware components is demonstrated. This is followed by practising the use of VR glasses and controllers, with a gradual adaptation to the immersive environment.

2) The second phase (exploration): This phase involves the formation of teams, the definition of hypotheses, research plans, and tasks. The teacher encourages collaborative learning and selects VR content for independent research. Students acquire experiential knowledge through virtual scenarios, with methodological instructions for active and reflective observation. It is recommended that activities be structured according to Digital Bloom's Taxonomy (Churches, 2010; J. Ristić, 2022) and directed towards achieving educational outcomes. Students can collect points in the immersive environment through play or conduct specific experiments by placing digital objects (instruments).

3) The third phase (collaboration and experience exchange): This phase involves reflecting on the VR experience through group discussions and the exchange of ideas. These activities aim to encourage abstract conceptualisation at both individual and collective levels. The teacher promotes joint problem-solving, experimentation, and presentation of results. Advanced students or university students can create virtual scenarios (360-degree with tags) at home, becoming prosumers, i.e., creators, and reaching the highest level of Digital Bloom's Taxonomy.

4) The fourth phase (evaluation): The results of the research are presented with reasoned communication, focusing on the innovative application of solutions. Self-evaluation is carried out through an online survey posted on the platform, aiming to assess the effectiveness of learning in the online immersive environment.

According to Mišćević & Bujišić (2023, p. 249), 'the main link between new technology and students is the teacher.' During each phase of the hybrid-immersive teaching model, the teacher organises, monitors, provides feedback, conducts formative evaluation, and may also summatively assess the final solution.

The focus of improving initial education for pre-service and in-service teachers is the systematic establishment of continuity between theory and practice (Matović, 2024) and methodological preparation for integrating innovative hybrid models is crucial (Vujović & Ristić, 2015). Their professional practice in undergraduate and master's studies should be based on a hybrid-reflective model (J. Ristić & M. Ristić, 2023) and continued through ongoing professional development in a digital learning environment (Ristić & Mandić, 2018).

CONCLUSION

The key to the purposeful methodological application of VR as a teaching technology in specific educational situations is understanding the interdependence of the technical, content-related and pedagogical subsystems. The analysis of the technical subsystem shows that immersion and interactivity depend on hardware performance, with 3D VR being more advanced than mobile VR. Despite the use of existing VR software, more specialised software is required for different educational situations at all levels. VR is most commonly used at higher educational levels and in fields such as engineering, medicine, STEM, biology, chemistry, geography, language learning, and sports as well as to simulate dangerous situations, like natural disasters, and train for safety procedures.

The analysis of the content of virtual scenarios revealed the key potentials of VR that contribute to experiential learning experiences, active perception and visualisation, particularly for studying abstract scientific concepts (DNA) and remote or inaccessible areas, motivation and creativity, development of

social skills – communication, empathy, and training in safe learning environments for the development and transfer of specialised motor skills.

The hybrid learning environment is flexible and stimulating, as well as the integration of different learning theories. This research shows that VR best fits into the concept of play-based, situated, creative experiential, social-cognitive, inquiry-based, trial and error, problem-based, transfer learning as well as learning by doing and cognitive theory of multimedia learning.

In this regard, the importance of reflecting on all constructs and pedagogically guided phases for the purposeful integration of VR into the proposed hybrid-immersive teaching model, based on the CSCL theory and explained through four phases (adaptation, exploration, collaboration and experience exchange, evaluation) is emphasised. Technology is brought into a symbiotic connection with learning, which is organized live/online in teams through precisely structured tasks with role division, with opportunities for online access to immersive content. Students collaboratively work on solving problem situations, which further implies that they hypothetically reason, share experiences, distribute information, explore in an immersive environment through VR technology, verify evidence, and ultimately engage in reasoned communication with the formulation of conclusions.

Teachers need to be trained to find technical alternative solutions (e.g., VR corners in schools/universities) to ensure equal access. Future research should focus on pilot testing the model's effectiveness at all educational levels and conducting longitudinal studies to assess its impact and tailor integration to different age groups.

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INTEGRACIJA VIRTUELNE REALNOSTI U FUNKCIJI HIBRIDNO-IMERZIVNOG OBRAZOVANJA

Sažetak: Uvođenje virtuelne realnosti kao nastavne tehnologije proširuje obrazovne mogućnosti hibridne nastave zahvaljujući komponenti imerzivnosti koja omogućava potpunije iskustveno učenje. Predmet ovog istraživanja je sistematizacija i analiza postojećih tehničkih, sadržajnih i pedagoških saznanja o svrsishodnoj integraciji virtuelne realnosti u nastavna okruženja, sa ciljem

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definisanja metodičkih i pedagoških osnova za razvoj prospektivnog hibridno-imerzivnog nastavnog modela. Rezultati dobijeni metodom komparativne analize deset naučnih studija slučaja ukazuju da se koriste raznovrsni hardverski setovi, u različitim nastavnim oblastima, na sva tri nivoa obrazovanja. Detektovano je deset pedagoških teorija učenja koje su poslužile kao osnova za realizaciju inovativnih obrazovnih aktivnosti sa tehnologijom virtuelne realnosti. Metodom modelovanja definisani su ključni metodički konstrukti i etape hibridno-imerzivnog nastavnog modela kao što su: adaptacija, istraživanje, saradnja i razmena iskustava, evaluacija.

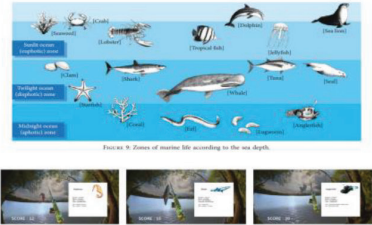
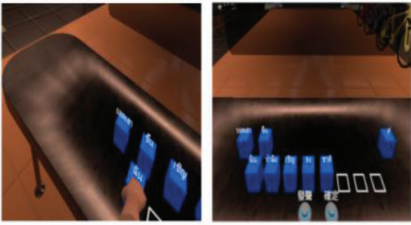
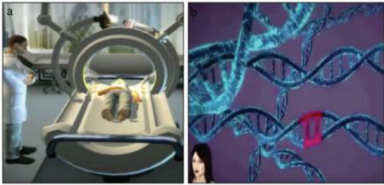
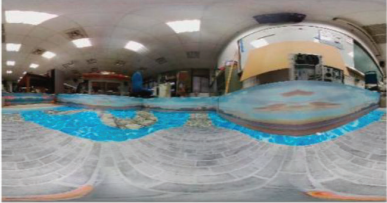
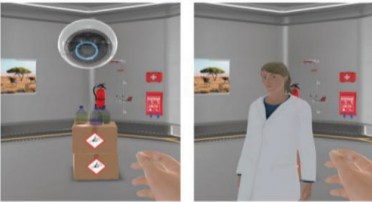
Ključne reči: virtuelna realnost, imerzivnost, hibridno nastavno okruženje, iskustveno učenje, obrazovna tehnologija

APPENDIX

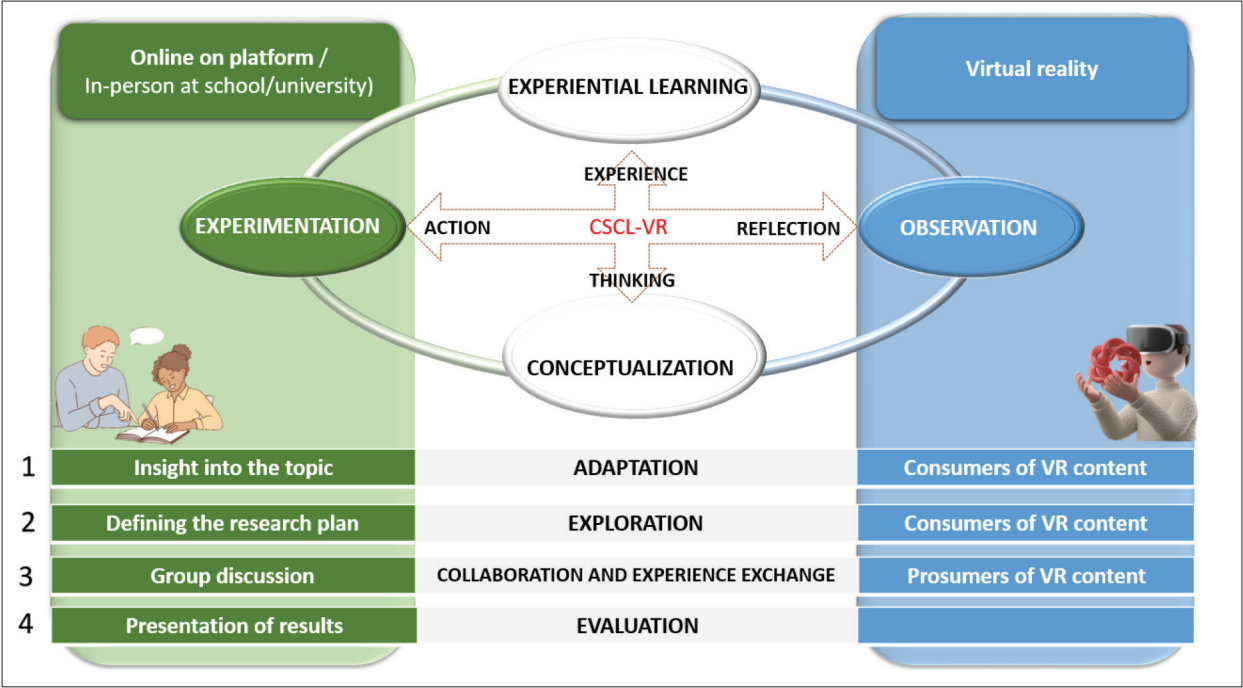
Table 1: Key Elements of the Technical, Content-related, and Pedagogical Subsystems of VR Educational Technology

	TECHNICAL SUBSYSTEM		CONTENT-RELATED SUBSYSTEM		PEDAGOGICAL SUBSYSTEM
Case studies	Hardware	Software	Field	Level ³	Learning Theory
Choi et al. (2018)	Samsung Gear VR	Unity3D engine	Biology	Secondary High	play-based learning
Babu et al. (2018)	HTC Vive	Unity 3D engine	Engineering	High	situated learning
Bhattacharjee et al. (2018)	Google Cardboard	Cardboard SDK	Chemistry and Biology	Secondary	learning by doing
Chang et al. (2020)	VR goggles	Franklin's Lab, Cyber Science 3D, Leopoldy	Art	Primary	creative experiential learning
Makransky et al. (2019)	Samsung Gear VR	EdTech Labster	STEM	Secondary	social-cognitive learning
Watthanapas et al. (2023)	VR Cardboard	Multi-language VR LAS	Foreign Language	High	cognitive theory of multimedia learning
Jong et al. (2020)	Google Cardboard	EduVenture-VR	Geography	Secondary	inquiry-based learning
Kennedy et al. (2023)	Oculus/Meta Quest 2	Arterial Blood Gas, Vantari VR	Medicine	High	trial and error learning
Feng et al. (2021)	Oculus Rift	Unity3D engine	Dangerous situation	Primary	problem-based learning
Markwell et al. (2023)	Oculus Rift	Cloudlands VR Minigolf	Sport	High	transfer learning

3 The education levels defined in Table 1 are adapted according to the categorisation of education levels in Serbia (Law on the Fundamentals of the Education System, *Official Gazette*, 92/2023. Available at https://www.paragraf.rs/propisi/zakon_o_osnovama_sistema_obrazovanja_i_vaspitanja.html).

	
Illustration 1: <i>Biology</i> (Choi et al., 2018)	Illustration 6: <i>Foreign Language</i> (Watthanapas et al., 2023)
	
Illustration 2: <i>Engineering</i> (Babu et al., 2018)	Illustration 7: <i>Geography</i> (Jong et al., 2020)
	
Illustration 3: <i>Chemistry and Biology</i> (Bhattacharjee et al., 2018)	Illustration 8: <i>Medicine</i> (Kennedy et al., 2023)
	
Illustration 4: <i>Art</i> (Chang et al., 2020)	Illustration 9: <i>Dangerous situation</i> (Feng et al., 2021)
	
Illustration 5: <i>STEM</i> (Makransky et al., 2019)	Illustration 10: <i>Sport</i> (Markwell et al., 2023)

Scheme 1: *Methodological Constructs and Phases of the Hybrid-Immersive Teaching Model (Modified from Ristić et al., 2023, pp. 276; J. Ristić, 2022, pp. 290; Jong et al., 2020, pp. 5–6; Punako, 2018, pp. 22; Huang et al., 2016, pp. 75; Chang et al., 2020, pp. 9)*



*Scheme 1: Methodological Constructs and Phases of the Hybrid-Immersive Teaching Model
(Modified from Ristić et al., 2023, pp. 276; J. Ristić, 2022, pp. 290; Jong et al., 2020, pp. 5–6; Punako, 2018, pp. 22; Huang et al., 2016, pp. 75; Chang et al., 2020, pp. 9)*