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THE ROLE OF VIRTUAL REALITY IN MODERN GEOGRAPHY EDUCATION: OPPORTUNITIES AND CHALLENGES

Abstract: *Virtual Reality (VR) is increasingly being integrated into geography education, providing immersive learning experiences that enhance spatial thinking, engagement, and conceptual understanding. This study explores the opportunities and challenges of incorporating VR in geography curricula. A mixed-methods approach was used, analyzing existing literature and conducting surveys among educators and students. The findings highlight the potential benefits of VR in improving student motivation and geographical skills while addressing technical, pedagogical, and financial barriers. The study provides recommendations for effective VR integration in geography education.*

This article discusses how Virtual Reality (VR) technologies, along with associated software and content, can serve as effective tools for teaching and learning in geography. Based on the authors' direct experience of incorporating VR into both undergraduate and postgraduate education, the article first examines how VR can support the development of students' fieldwork observation skills and deepen their understanding of specific places before engaging in real-world field experiences. Next, the article explores how VR can help students build critical thinking and analytical skills, particularly in relation to emerging visual technologies and the broader impact of VR on how people, places, and landscapes are represented. Lastly, it highlights how both VR and Augmented Reality (AR), given their increasing use in industry, can help students acquire distinctive

practical skills that are valuable for geovisualization tasks—thus enhancing their future employability in geography-related careers.

Key words: *Virtual Reality, Geography Education, Spatial Thinking, Virtual reality (VR); fieldwork; employability; critical analytical skills; visual analysis; augmented reality (AR) Immersive Learning, Digital Pedagogy, Digital Mapping, Geospatial Analysis.*

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РОЛЬ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ В СОВРЕМЕННОМ ГЕОГРАФИЧЕСКОМ ОБРАЗОВАНИИ: ВОЗМОЖНОСТИ И ПРОБЛЕМЫ

Аннотация: *Виртуальная реальность (VR) все чаще интегрируется в географическое образование, обеспечивая иммерсивный опыт обучения, который улучшает пространственное мышление, вовлеченность и концептуальное понимание. В этом исследовании изучаются возможности и проблемы включения VR в учебные программы по географии. Был использован смешанный подход, анализ существующей литературы и проведение опросов среди преподавателей и студентов. Результаты подчеркивают потенциальные преимущества VR в улучшении мотивации студентов и географических навыков при одновременном устранении технических, педагогических и финансовых барьеров. В исследовании даются рекомендации по эффективной интеграции VR в географическое образование.*

В этой статье обсуждается, как технологии виртуальной реальности (VR), а также связанное с ними программное обеспечение и контент могут *служить эффективными инструментами для преподавания и обучения географии. Основываясь на непосредственном опыте авторов по внедрению VR в бакалавриат и аспирантуру, в статье сначала рассматривается, как VR может поддержать развитие у студентов навыков наблюдения за полевыми работами и углубить их понимание конкретных мест, прежде чем приступить к реальным полевым опытам. Затем в статье рассматривается, как VR может помочь студентам развить критическое мышление и аналитические навыки, особенно в отношении новых визуальных технологий и более широкого влияния VR на то, как представлены люди, места и ландшафты. Наконец, в ней подчеркивается, как и VR, и дополненная реальность (AR), учитывая их растущее использование в промышленности, могут помочь студентам приобрести особые практические навыки, которые ценны для задач геовизуализации, тем самым повышая их будущую трудоустраиваемость в карьерах, связанных с географией.*

Ключевые слова: *Виртуальная реальность, Географическое образование, Пространственное мышление, Виртуальная реальность (VR); полевые работы; трудоустройство; критические аналитические навыки; визуальный анализ; дополненная реальность (AR) Иммерсивное обучение, Цифровая педагогика, Цифровое картографирование, Геопространственный анализ.*

Introduction

In today's digitally literate society, education is encountering challenges that highlight the necessity of re-evaluating traditional paper-and-pencil teaching methods. As digital tools continue to advance, future professions are becoming more complex, requiring university graduates to develop digital skills in order to thrive in an ever-evolving information landscape.

The key directions of the digitalization process include:

- Personalization of learning experiences (customized educational approaches).
- A general decline in reading habits.
- Increased accessibility of education.
- Ensuring information security.
- The integration of gamification into education.

The advancement of digital technologies has significantly influenced educational methodologies, with Virtual Reality (VR) emerging as a promising tool in geography education. VR enables students to experience geographical phenomena interactively, reducing the limitations of traditional classroom-based learning. However, despite its benefits, the integration of VR in geography curricula presents multiple challenges, including accessibility, cost, and pedagogical adaptation. This study aims to explore both the advantages and limitations of VR implementation in geography teaching.

The teaching of geography has progressively shifted towards a more practical approach, emphasizing the application of geographical knowledge and skills through digital solutions, ICT tools, and innovative methodologies (González, 2014). The impact of technological advancements, including digital content and teaching methods, is now deeply embedded in geography education, influencing curriculum design, study materials, classroom activities, and learning objectives in line with the International Charter on Geographical Education (IGU-CGE, 2016). As educational technology continues to evolve, new pedagogical approaches have emerged, aiming to integrate technology-driven methods into geography lessons, leveraging the subject's interdisciplinary nature and the ongoing digital transformation of society (Hazen, 2020).

Despite these advancements, the significance of geographic knowledge and the status of geography as a subject in Hungarian public education have gradually diminished over the past two decades. Changes in national curricula—revised twice within 15 years—along with a limited number of weekly lessons (1-2-2-1 from Grades 7 to 10) and a decline in students opting for intermediate-level school-leaving exams have contributed to geography being perceived as a less relevant subject (Chrappán, 2020), (Probáld, 2017). Research indicates that while students generally express an interest in geography and enjoy the subject, they do not view it as particularly important or useful, making it challenging to convey the relevance of geographical knowledge and maintain student motivation (Chrappán, 2020). The only notable improvement has been an increase in advanced-level final exam participation, primarily due to its relevance in university admissions for agricultural and economic studies.

LITERATURE REVIEW

Numerous studies have examined the role of VR in education, particularly in geography. Table 1 presents key studies on VR applications in geography teaching. Virtual Reality (VR) is a platform that provides a variety of digital tools and services, supporting diverse teaching and learning activities. The adoption of VR in higher education began nearly a decade ago, focusing primarily on teacher training to equip future educators with the skills needed to navigate technology-rich learning environments, where information consumption is facilitated by information and communication technology (ICT).

Table 1. Key studies on VR applications in geography teaching.

Study	*Focus Area*	*Key Findings*
Smith et al. (2020)	Spatial Thinking	VR enhances students'

		ability to visualize geographic data.
Johnson & Lee (2019)	Fieldwork Simulation	VR reduces logistical challenges of real-world fieldwork.
Brown et al. (2021)	Student Engagement	VR increases motivation and knowledge retention.
Wilson (2022)	Pedagogical Integration	Effective use of VR requires teacher training and curriculum redesign.

The use of VR in education dates back to the early 21st century T. (Monahan 2008) and has been integrated into multiple teaching strategies and scientific disciplines. One of its most prevalent applications is in e-learning (B.Lampert 2018), though it can also complement traditional instructional methods. For example, VR plays a crucial role in medical education, enhancing the effectiveness of learning materials (J.Falah 2014), (S.Jang 2017) and addressing rehabilitation challenges (A. Gilányi 2017), (M.Yates 2016). In engineering, VR is increasingly utilized both as an educational tool (I.Horváth 2016) and a professional workspace. Additionally, VR is being applied in business training to enhance various professional competencies (L. Kiss 2015), (A.Tarabasz 2018). Research findings indicate that VR has a profound impact on educational processes, improving cognitive skills such as creative thinking and problem-solving (Gy. Bujdosó 2017), (R. Hu 2016). Moreover, studies reveal that VR environments positively influence soft skills like collaboration and teamwork (Gy. Bujdosó 2017), (V. Kövecses-Gősi 2018), providing learners with opportunities to develop a broad spectrum of abilities.

METHODOLOGY

This research conducted an in-depth evaluation of the integration of digital platforms in geography education. Initially, an extensive literature review was carried out to examine the effects of GIS, VR, AR, and interactive maps on the learning process. A quantitative approach was employed, collecting data from 50 secondary school classes. Students were divided into two groups: one received instruction through traditional teaching methods, while the other utilized GIS and VR/AR technologies. Over several weeks, spatial reasoning abilities, engagement levels, and overall knowledge retention were assessed, and the academic performance of both groups was compared. Statistical analysis was conducted using SPSS software, with results deemed statistically significant at $p < 0.05$.

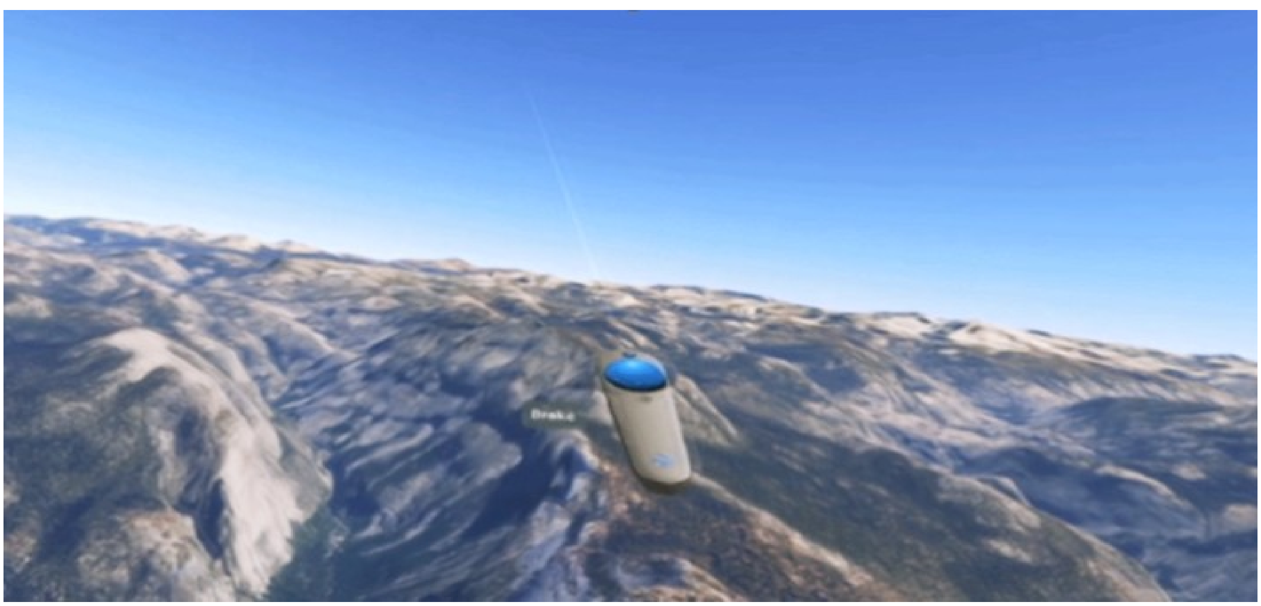
Furthermore, interviews with teachers and students provided insights into the reception of these technologies in the classroom and their overall effectiveness. This methodological approach ensures the reliability and scientific validity of the findings, offering a clearer understanding of the role of digital tools in geography education.

FINDINGS AND DISCUSSION

Virtual reality (VR) technologies significantly enhance the learning experience by making it more visual, engaging, and interactive. Through computer-generated environments that respond to user input, learners are immersed in lifelike simulations that enrich understanding. In the field of experimental education, VR offers students an intuitive and immersive way to explore real-world scenarios (Zhang et al., 2020).

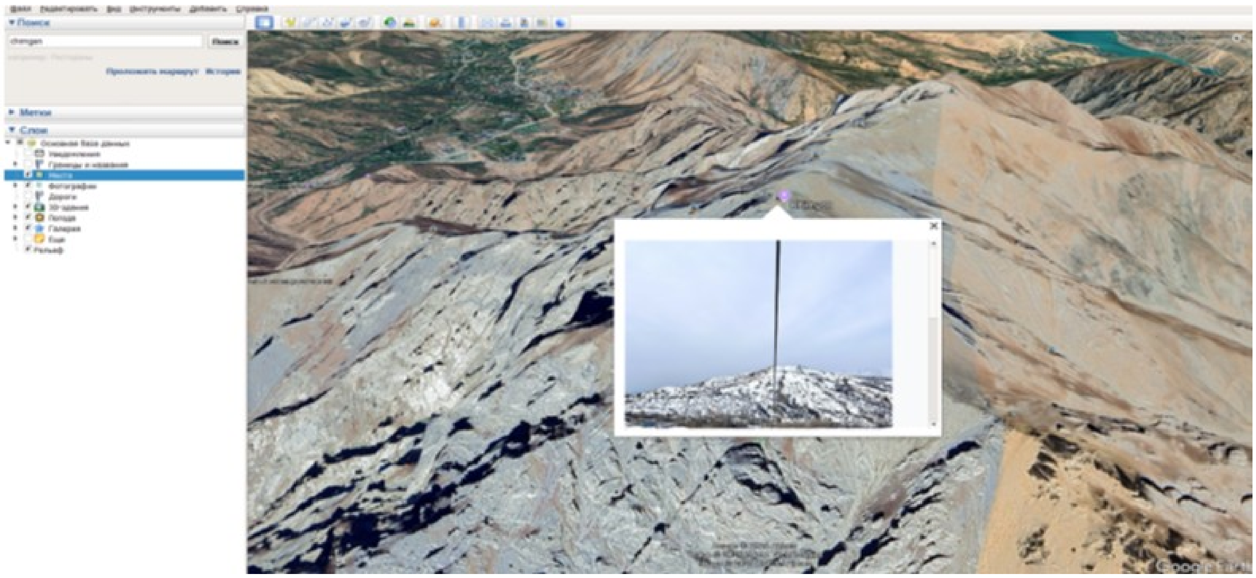
One practical application is a forensic investigation simulation, where learners engage in virtual lab activities to examine and analyze crime scenes using digital tools. These VR-based modules combine theoretical lectures with hands-on virtual labs, allowing students to assume the role of an investigator. A sample scenario begins with a company CEO expressing concerns over internal data breaches and hidden stolen blueprints. The instructor then tasks students with locating the blueprints and collecting relevant evidence for forensic analysis (Hassenfeldt et al., 2020).

Meanwhile, Google's Google Earth VR project illustrates another innovative use of VR by enabling users to explore famous global landmarks such as the Eiffel Tower, Egyptian Pyramids, or Niagara Falls in a fully immersive environment. Users can even simulate space travel and view Earth from a shuttle's perspective. The application allows for navigation through changes in altitude, direction, and even time of day, all controlled via VR headset controllers. Freely accessible, Google Earth VR makes planetary exploration possible without leaving home.



(**Figure 1.** Google Earth VR Application)

Various VR technologies have been utilized as pedagogical tools, often emphasizing hardware such as VR Head-Mounted Displays (HMDs) like Oculus Rift (Moro et al., 2017), Google Cardboard (Stojšić et al., 2017), and Samsung Go. However, these approaches tend to overlook supplementary technologies and software essential for VR content creation, such as 360-degree cameras (GoPro Max 360, Samsung Gear 360), virtual tour software (ThingLink, TourWeaver), and additional hardware like Augmented Reality Sandboxes.



(**Figure 2**. View of the Chimgan Mountains through Google Earth)

It is crucial to explore the diverse range of VR and AR technologies, their potential applications in education, and the practical aspects of their classroom integration. This paper specifically examines how VR and AR can be effectively utilized in teaching, with a focus on enhancing fieldwork experiences, developing students' critical analytical skills, and preparing them for a job market that increasingly relies on technology (Davis, 2017). To support this, the study draws on firsthand experiences of using VR in teaching, presenting case studies and student feedback from surveys to demonstrate its effectiveness as an educational resource.

VR technology was utilized to prepare for an annual first-year human geography residential field trip held in the Chimgan Mountains, Uzbekistan. The fieldwork centered on the concept of “living landscapes,” examining diverse cultural, economic, social, and political issues present in the area. Before the trip, students attended a series of preparatory lectures that introduced both theoretical frameworks and methodological approaches for studying landscapes, enabling them to design independent group projects.

Prior to the field trip, a collection of static 360-degree images and video footage was captured from various field sites using a Samsung Gear 360 camera. The recorded content was then processed with specialized software and uploaded to Oculus Go headsets. The integration of VR technology provided valuable learning opportunities to help students prepare for fieldwork.

Firstly, the VR headsets allowed students (n = 6) to observe and immerse themselves in the landscapes they would later visit in person. Using footage from near the peak of Greater Chimgan, the highest mountain in the region and a popular tourist destination, students worked in pairs to analyze human influence on the landscape and identify emerging socio-spatial issues. According to student feedback, this activity helped them maintain focus on a specific location while enhancing their ability to “look [and] listen for different things.” Additionally, the immersive nature of the headsets minimized external distractions, allowing them to “focus more on the environment.” However, some students noted that occasional pixelation in the footage reduced the overall VR experience, making it more difficult to distinguish key landscape features.

Secondly, VR technology enabled students to practice observational techniques and explore both qualitative and quantitative approaches to landscape studies within a classroom setting. Specifically, the methodology was influenced by the "Mapping Tranquility" report from the Campaign to Protect Rural England

(CPRE), which employs a quantitative framework to assess factors that enhance or diminish perceptions of tranquility. By using VR, students could apply these techniques beforehand, systematically identifying both visual and auditory attributes of tranquility within the virtual landscape. This approach allowed them to refine their methodological skills in advance, reducing the need for extensive training in the field.

Finally, a crucial part of fieldwork preparation within academic institutions involves identifying, assessing, and documenting potential risks and hazards (Higgitt & Bullard, 1999). The VR content allowed students to examine the landscape for possible dangers, such as uneven terrain, roads, vehicles, and potential interactions with both human and non-human elements. The 360-degree view helped students spatially contextualize the landscapes they would explore, while the visual-audio footage provided insights into challenging weather conditions—a significant factor in the Chimgan Mountains, particularly during winter. This process fostered collaboration as students worked together to complete the risk assessment, equipping them with the necessary skills for their own risk assessment submissions later in their studies.

(**Figure 3**. A 360-degree image captured using a Samsung Gear 360 camera at the summit of Greater Chimgan, Uzbekistan) (Source: Authors).

Table 2. Benefits of VR in Geography Education

Benefit	*Description*

Improved Visualization	VR helps in understanding complex topographical data.
Enhanced Student Engagement	Students show higher motivation and participation.
Simulated Fieldwork	Reduces costs and logistical barriers to real-world geography studies.
GIS Integration	Combining VR with GIS enables advanced spatial analysis.

Table 3. Challenges and Solutions for VR in Geography

Challenge	*Proposed Solution*
High costs	Funding through grants and public-private partnerships.
Technical limitations	Investing in cloud-based VR solutions.
Lack of teacher training	Organizing VR workshops for educators.
Accessibility Issues	Providing affordable VR headsets to schools.

CONCLUSION AND RECOMMENDATIONS

This study has highlighted various ways in which virtual reality (VR) technologies can serve as valuable tools to enrich the teaching and learning of geography. The examples discussed demonstrate that VR and augmented reality (AR) can effectively stimulate student interest and participation in essential fieldwork activities, foster critical visual interpretation skills, and potentially improve future employment opportunities as these technologies gain traction in commercial settings.

Nonetheless, several challenges must be addressed. These include limited access and high costs associated with acquiring such technologies for educational institutions, as well as the need for adequate staffing and resources to deliver effective instruction. Additionally, the rapid development of the VR and AR industries demands regular hardware updates and continuous improvement of technical competencies and knowledge.

From the learners' perspective, engagement levels with VR/AR tools can differ significantly among individuals. This suggests a need for further investigation into how student characteristics influence their interaction with immersive technologies, and how this variation affects pedagogical approaches. Moreover, VR headsets have been reported to cause motion sickness in some users, which may result in their exclusion from learning experiences.

Despite these challenges, the study underscores the promising role of VR and AR in enhancing student motivation and in supporting the development of essential geographical knowledge and skills. In some cases, familiarity with these technologies may also provide a competitive edge in the job market for graduates.

Based on the findings of this study, several key recommendations can be made to improve the integration and effectiveness of VR/AR technologies in geographical education:

- Educational institutions should seek strategic investments or partnerships to make VR/AR technologies more affordable and accessible. Grants or public-private collaborations can help reduce the cost barriers for departments.
- Regular training programs should be implemented to ensure that educators and technical staff stay updated with evolving VR/AR tools. Building internal expertise is crucial for the sustainable use of immersive technologies in classrooms.
- VR/AR should be purposefully embedded into the geography curriculum to enhance learning outcomes—especially in fieldwork-based modules, environmental modeling, or spatial analysis. Such integration should align with learning objectives and not be used as novelty.
- Special attention must be given to students who experience motion sickness or other discomforts when using VR headsets. Alternative formats or adaptive methods should be developed to ensure inclusive participation.
- Continued research is needed to explore how different student characteristics (e.g., learning styles, digital literacy levels, socio-economic backgrounds) affect engagement with VR/AR. This can help tailor pedagogical approaches for diverse learners.
- Incorporating VR/AR skills into student learning portfolios can enhance their competitiveness in the job market. Institutions should align VR-based activities with real-world applications and industry needs.

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