GeoSpatial Virtual Reality & Planning AR Laboratory for education in spatial planning

Author's Name: Katarzyna Rędzinska, PhD
Affiliation: Faculty of Geodesy and Cartography, Warsaw University of Technology

Email:katarzyna.redzinska@pw.edu.pl

Abstract
This paper presents outcomes from a pioneering educational project funded by Warsaw University of Technology during the 2022/2023 academic year. The project aimed to establish a mobile Virtual Reality (VR) Laboratory supporting teaching in geoinformation, spatial planning, urban planning, and architecture. Leveraging the expertise of the Faculty of Geodesy and Cartography and the Faculty of Architecture, the laboratory promoted an interdisciplinary approach to geospatial analysis and planning. The project comprised six tasks, including organizing the laboratory, conducting pilot implementations, and developing interdisciplinary workshop scenarios. Five pilot implementations utilized VR technology in various aspects of the spatial planning process, receiving positive feedback from students and partners. The project facilitated student engagement, exchange of teaching practices, and expansion of academic offerings.

Keywords: augmented reality, co-creation, collaborative design, geospatial technologies

Full text

1. Introduction

The significance of Virtual Reality (VR) technology in spatial planning education is increasing, aligning with its growing importance in related industries. Higher education serves as the primary application field offering a novel educational environment, an immersive teaching system, and opportunities for remote education. Despite over a hundred publications addressing VR technology applications in education, limited information exists specifically on its use in spatial planning. VR technology presents various opportunities in education, including immersive learning environments for visualization and 3D modeling, as well as creating diverse educational products. (Figure 1, Figure 2). However, challenges remain to be addressed.

VR technologies have the potential to revolutionize spatial and urban planning education by providing enhanced (immersive) learning experiences (Sanchez-Sepulveda et al., 2019, van Leeuwen et al., 2018, Pouke et al., 2019, Vats and Joshi, 2024), improving usability and effectiveness (Sanchez-Sepulveda et al., 2019, Zhang and Moore, 2014, Zuo et al., 2023), promoting stakeholders participation (van Leeuwen et al., 2018, Sabah et al., 2023), and offering realistic visualizations of urban spaces (Pouke et al., 2019, Schauppenlehner et al., 2018). Additionally, it enhances learning outcomes and student interest (Schauppenlehner et al., 2018). According to Vats and Joshi (2024), Wai Yie et al. (2023), Cicek et al. (2021), VR has the potential to engage students on a deeper level, making education more interactive and enjoyable, thus fostering curiosity, creativity, critical thinking, and problem-solving skills.

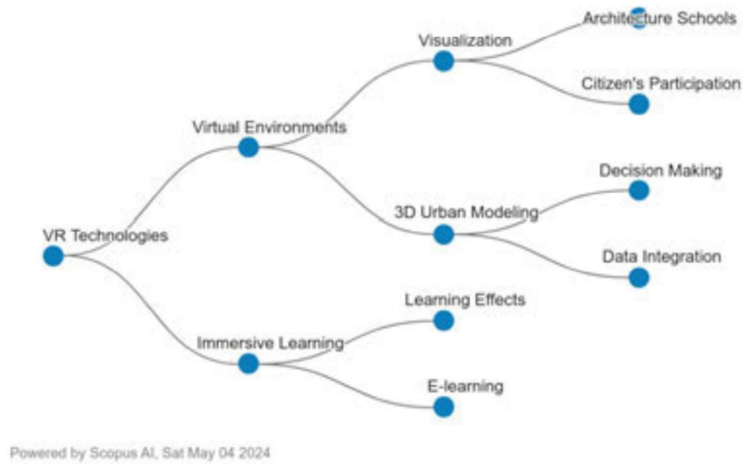

Figure 1. VR technologies applications in planning education

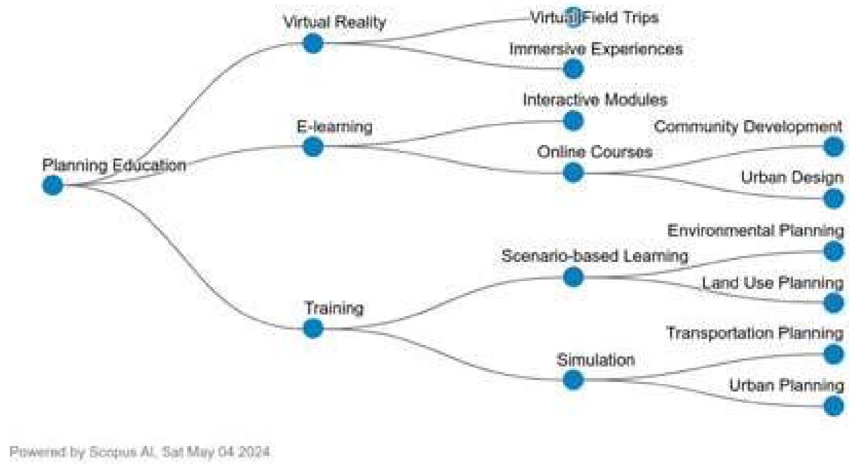

Figure 2. Various educational products using VR technology

As an Active Learning Tool VR involves visualization and interactivity with virtual dynamic and complex systems (Talbi et al., 2023, Vats and Joshi, 2024). Through skill development and training, VR offers opportunities to improve spatial understanding, engagement, motivation, and learning outcomes (Holubinka et al., 2023, Elaish et al., 2024, George et al., 2022). Stewart and Lopez (2021) claim that VR contributes to developing spatial visualization skills with increased student motivation and better performance (Figure 3).

VR supports collaborative design processes in architecture and urban planning education by facilitating remote, real-time collaborative work, and spatial comprehension (Wagemann and

Martínez, 2022, Tran et al., 2024). VR as a communication medium in urban planning and design provides decision-makers with access to a shared virtual space, impacting decision-making processes (Roupé and Gustafsson, 2013, Sanchez-Sepulveda et al., 2019). As such, VR serves as a social participation tool (Figure 4).

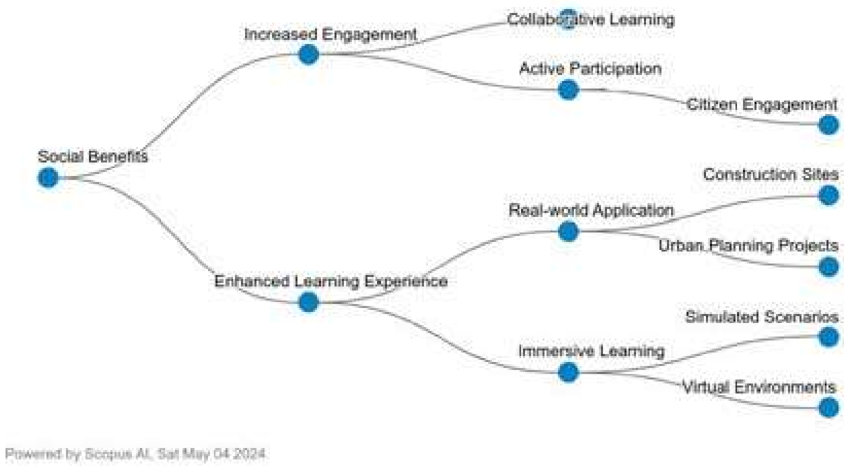

Figure 3. Students engagement in learning process involving VR technology

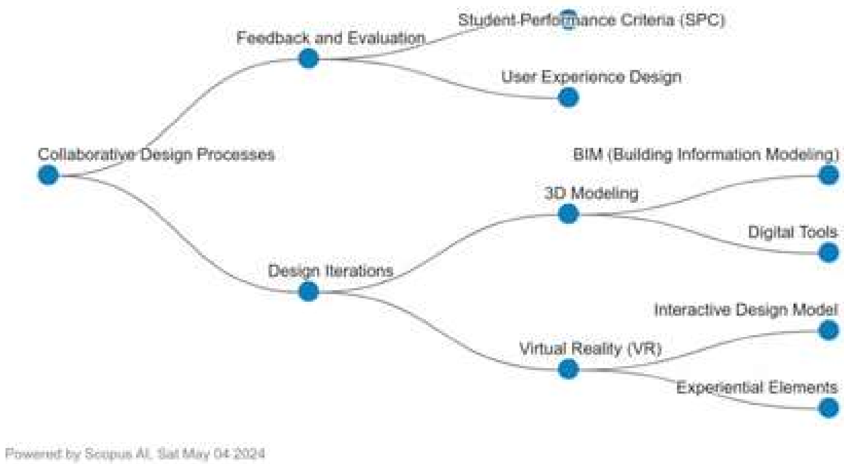

Figure 4. Supporting collaborative design process by VR technology

The interdisciplinary potential of VR technology spans spatial planning, urban planning, architecture, and geoinformation domains (Conesa-Pastor et al., 2022; Wu et al., 2021; Zang et al., 2021; Zhang and Li, 2021).

Regarding challenges in integrating VR technologies into planning education, there is a need to consider economic, technical, and ethical issues.

In terms of economic challenges, the high costs for content development and educator training have been identified as barriers to widespread and effective adoption in educational programs (Kencevski and Zhang, 2019), Additionally, the costs of hardware and software, ongoing maintenance, and the necessity for strategic planning and investment to effectively utilize VR in education pose significant economic challenges (Talbi et al., 2023, Vats and Joshi, 2024, Elaish et al., 2024). However, the potential benefits of improved learning outcomes and increased student engagement may offer a positive return on investment in the long term (Vats and Joshi, 2024, Elaish et al., 2024).

Technical challenges encompass integrating appropriate hardware and software, which can be costly and require regular updates to keep up with technological advancements (Wai Yie et al., 2023). VR equipment needs technical support and maintenance, including troubleshooting and software updates (Holubinka et al., 2023, McGrath, 2019). Moreover, ensuring equal access to VR technologies for all students, regardless of their socioeconomic background, is a significant challenge that needs to be addressed (Talbi et al., 2023, Vats and Joshi, 2024). According to Talbi et al. (2023), Riemann et al. (2020) Vats and Joshi (2024), and Rangarajan et al. (2024), the technological limitations of VR need to be overcome to ensure effective integration into education programs. As using VR requires technical knowledge, individual engagement in urban planning can be limited, and learning costs can hinder citizen participation (Sabah et al., 2023) (Figure 5).

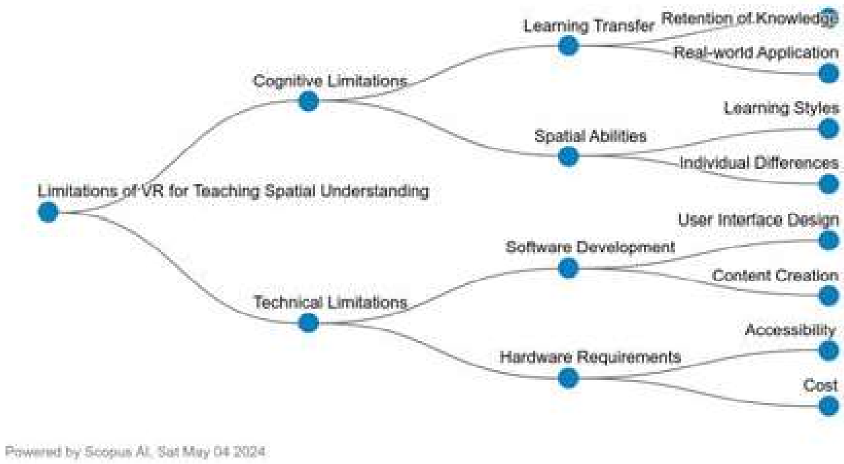

Figure 5. Limitations of VR for teaching spatial understanding

Ethical considerations associated with the use of VR technologies in Urban Planning Education relate to physiological and cognitive impacts, behavioral and social dynamics, and the need for ethics in practice in their use (Kenwright, 2018). Ethical considerations also include ensuring equitable access to VR technologies for all students (Talbi et al., 2023). Moreover, implementing VR in education requires addressing privacy and data security concerns related to collecting and using student data within virtual environments (Wai Yie et al., 2023) (Figure 6 and 7).

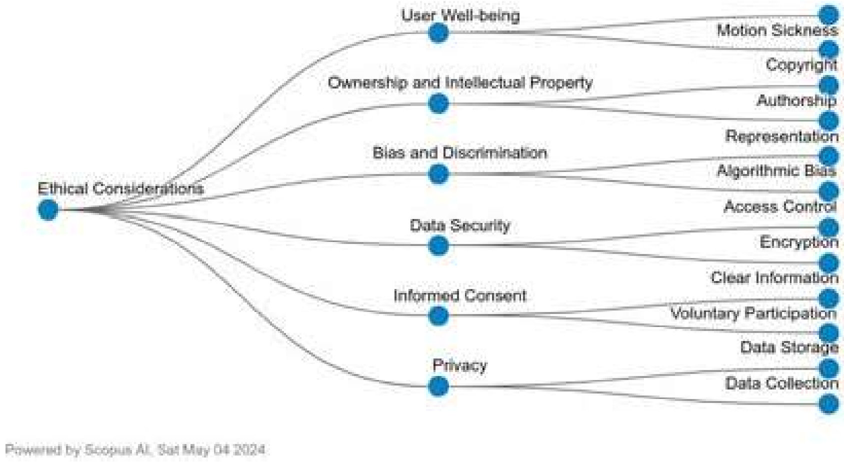

Figure 6. Ethical consideration in VR impemention into didactics

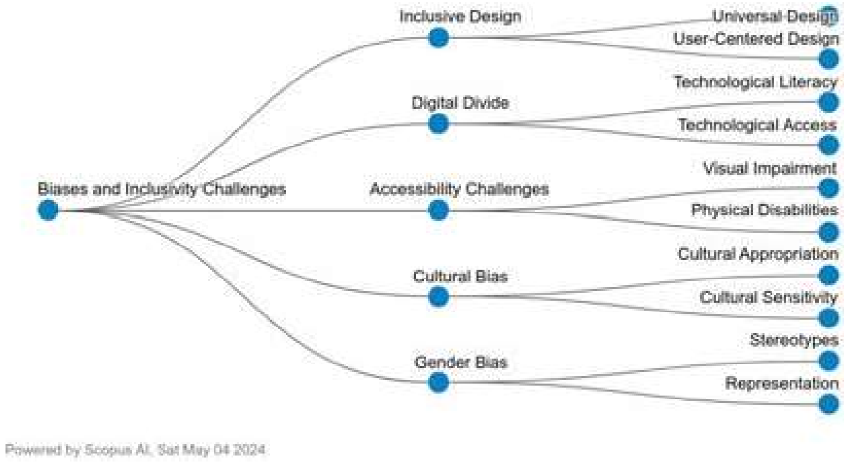

Figure 7. Biases and Inclusivity challenges

Further research is needed to understand the pedagogical effectiveness of VR in education and address associated considerations and challenges (Elaish et al., 2024, Holubinka et al., 2023).

This paper unveils the outcomes of a groundbreaking didactic project funded by Warsaw University of Technology (IDUB - Excellence Initiative - Research University) during the academic year 2022/2023. The project aimed to establish a mobile Virtual Reality Laboratory supporting didactics in geoinformation, spatial planning, urban planning, and architecture. Leveraging the distinct competencies of the Faculty of Geodesy and Cartography and the

Faculty of Architecture, the laboratory fostered an interdisciplinary and comprehensive approach to geospatial analysis and spatial planning. The goal of establishing the VR Laboratory was to enable:

- Activation of students through creative teamwork in solving design problems (spatial planning, urban planning, and architecture) in augmented reality.
- Skills development of geodesy and cartography students in processing geospatial data to create terrain and interior building models for Virtual Reality, and geoinformatics students in creating new geoinformation applications using VR technology (including creating Digital Twins).
- Exchange of good teaching practices through international cooperation by implementing joint, interdisciplinary, remote classes in VR/AR.
- Technological innovations, increasing academic teachers' qualifications in new digital technologies, and modern education methods.

2. Results

The project comprised six tasks: 1) organizing the laboratory; 2) conducting five pilot implementations in teaching; 3) developing an interdisciplinary planning workflow workshop scenario; 4) undertaking science popularization actions; 5) promoting among departments; and 6) formulating a future deployment plan. The pivotal aspect was the execution of five pilot didactic implementations, each employing VR technology for various purposes in varied learning environments and formulas within the spatial planning process. The interdisciplinary team conducted the implementations.

The first implementation was an international and interdisciplinary workshop in collaboration with landscape architecture at the American University of Beirut (AUB), Lebanon. It was integrated into an undergraduate spatial planning course on Revitalization projects led by Dr. Eng. Agnieszka Wendland. The workshop took place on December 15, 2022. It was organized by the Department of Geodesy and Cartography of the Warsaw University of Technology. During the semester, students prepared the study area model in the VR environment and uploaded useful objects to the library. The workshop was held in a VR environment using the GravitySketch® application. During the workshop, spatial planning students (GiK PW - one design group) co-created design solutions in cooperation with landscape architecture students of AUB, The Faculty of Agricultural and Food Sciences, Department of Landscape Design and Ecosystem Management. It was a real-time remote interdisciplinary and multicultural collaboration and co-creation in the VR learning environment. Thirty-five students participated in the workshop (20 online, 15 on-site). The on-site users could observe the workflow on the projector, computer screen, or phone, allowing more participants to engage in the process. Lessons learned regarding the benefits of the deployed workshop formula are: a) VR learning environment enabled a better experience of the space and conscious engagement, b) students have developed effective communication and collaboration skills, utilizing the VR platform for shared experiences, feedback, and collective design exploration; c) through interactive and immersive experiences, VR fostered motivation, participation, and a sense of enjoyment in the learning process, d) through iterative refinement and visualization in VR, students have honed their ability to make informed design decisions, optimizing the visual and functional aspects of the landscape (Dreksler et al., 2023).
The WiFi, Software and Hardware limitations were also observed. Data processing can be challenging on mounted gear with low computing power or low Internet connection. Most

students could only work 30-40 minutes at a time. The process could be chaotic if the group is to big or the students are not properly trained (Dreksler et al., 2023).

The creation of a new facultative course, "Systemic Design for Sustainable Development," was the second implementation. The course is accessible to all Erasmus students under the graduate specialization Mobile Mapping and Navigation Systems by Dr. Eng. Katarzyna Rędzińska. The course was chosen by the students and implemented in the summer semester 22/23. Six international and interdisciplinary students participated in the course. The course was held in the Arkio® software environment. It had a workshop formula using systemic design tools, PBL, and a learning-by-doing method in four-hour modules. The design challenge addressed the possible involvement of Warsaw University of Technology in the NetZero race campaign - redesigning the University Campus (https://unfccc.int/climate-action/race-to-zero-campaign). The Virtual (augmented) reality technology was used in the prototyping phase of the developed design solutions. This implementation provided evidence of the enhancement of student engagement and learning outcomes. Students developed collaboration and communication skills and teamwork. A small group of participants allowed to avoid chaos in the process. Short lectures, on-site teamwork on the systemic design templates (Jones and van Ael, 2022), and design considerations separated the 30-minute VR session. The technical limitations, such as WiFi, software updates, and hardware (battery efficacy), appeared similar to those in the first implementation.

The third implementation involved integrating a VR camera in a landscape planning course for graduate spatial planning students led by Prof. Adrianna Czarnecka. The course assignment was to plan nature-therapy trails in collaboration with the Urban Forests of Warsaw. Through the use of VR technology, students were able to exchange experiences of landscape perception in VR reality. The materials developed by the students will serve for educational purposes, implemented at the Center for Nature and Forestry Education led by the Urban Forests of Warsaw. They will potentially be used as an encouragement to visit Warsaw's forests or as an interactive guide. This implementation is an example of the socioeconomic environment's partner involvement. The above-mentioned benefits and limitations were also confirmed.

Practical testing of VR environment-developed models, including GIS and BIM technology, incorporated into three courses on cartographical modeling for graduate geodesy and cartography students was the focus of the fourth implementation. The implementations covered 46 students and were conducted by Msc Miłosz Gnat. The courses did not involve teamwork and co-creation. VR technology benefits provided enhanced student engagement and learning outcomes. As the headsets were connected to the computers, there were only limitations regarding the students' well-being (30-minute work time sessions).

Last but not least, the implementation allowed students to experience public spaces as blind persons in an undergraduate spatial planning course on Public Spaces Planning and Design. The implementation consisted of an interactive projection of a blind person's experience of public spaces, "Notes on Blindness" by TV Arte. The students were tasked with answering the question of how this experience would contribute to the understanding and consideration of the needs of blind people in the process of designing the spatial development of public spaces. The implementation was optional. The class was carried out in three groups of 10-15 people each. Similar to the previous implementation, it was an individual experience, enriching the urban design studio. It benefited by augmenting students' engagement and a better understanding of the need for universal planning and design.

Four science popularization activities enabled the testing VR technology as a participatory, co-creation tool.

3. Conclusions

The project's VR implementations provided evidence of the benefits of deploying VR technology in spatial planning and urban design education, as mentioned in the literature. The project's realization facilitated the activation of students through creative teamwork, the exchange of good teaching practices, the enhancement of teachers' qualifications in digital technologies, and the expansion of the didactic offer. All implementations received positive evaluations from participating students and partners.

However, the project also encountered challenges. Its outcome was to provide the VR Laboratory to ensure equal accessibility to the novel technology for students. The development of procedures and regulations can address the technological and ethical limitations. While challenges of integrating VR technologies into planning education exist, the opportunities for enhancing the educational experience and developing essential skills are evident from the literature and the project's results.

Implementations two, four, and five will continue in their present form. The international workshop will be embedded into a new optional joint course with AUB. Further research is crucial to understand the pedagogical effectiveness of VR in education and to guide future policy.

References

CICEK, I., BERNIK, A. & TOMICIC, I. 2021. Student thoughts on virtual reality in higher education—a survey questionnaire. Information (Switzerland), 12.

CONESA-PASTOR, J. & CONTERO, M. 2022. EVM: An Educational Virtual Reality Modeling Tool; Evaluation Study with Freshman Engineering Students. Applied Sciences (Switzerland), 12.

DREKSLER, B., RĘDZIŃSKA, K., WENDLAND, A. Designing the Future: A Pilot Workshop on Virtual Reality in Landscape Architecture Education. ECLAS Conference Labyrinth of the World. Landscape Crossroads. Mendel University in Brno and Lednice, Czech Republic, 10. – 13.09.2023

ELAISH, M. M., YADEGARIDEHKORDI, E. & HO, Y. S. 2024. Publication performance and trends in virtual reality research in education fields: a bibliometric analysis. Multimedia Tools and Applications.

GEORGE, B. H., FERNANDEZ, J. & SUMMERLIN, P. 2022. The Impact of Virtual Reality on Student Design Decisions: Assessing Density and Proximity When Designing in Virtual Reality Versus Traditional Analog Processes. Landscape Journal, 41, 31-44.

HOLUBINKA, K., URLINGS, C., STOYANOV, S., DEL PILAR SOSA-FERNÁNDEZ, R., MÉNDEZ-FERNÁNDEZ, R., CASTELLÓ-MAYO, E., KLEMKE, R. & DE GROOT, R. Implementing a Desktop VR Tool in a European University: Priorities and Challenges. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2023. 104-117.

JONES, P., VAN AEL, K. 2022. Design Journeys through Complex Systems: Practice Tools for Systemic Design. BIS Publishers BV; Edycja 1, Amsterdam, pp. 240

KENCEVSKI, K. & ZHANG, Y. A. 2019. VR and AR for Future Education. Handbook of Mobile Teaching and Learning: Second Edition.

KENWRIGHT, B. 2018. Virtual Reality: Ethical Challenges and Dangers [Opinion]. IEEE Technology and Society Magazine, 37, 20-25.

MCGRATH, O. G. AR/VR strategy considerations for academic computing services. Proceedings ACM SIGUCCS User Services Conference, 2019. 15-18.

POUKE, M., YLIPULLI, J., RANTALA, S., ALAVESA, P., ALATALO, T. & OJALA, T. A Qualitative Study on the Effects of Real-World Stimuli and Place Familiarity on Presence. 2019 IEEE 5th Workshop on Everyday Virtual Reality, WEVR 2019, 2019.

RANGARAJAN, V., BADR, A. S., SANCHEZ, C. & DE AMICIS, R. A Study on Educators' Requirements for Integrating VR in Post-secondary Classes. Lecture Notes in Mechanical Engineering, 2024. 405-413.

RIEMANN, T., KREß, A., ROTH, L., STAIGER, B., METTERNICH, J. & GRELL, P. 2020. Virtual reality in vocational training. ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb, 115, 673-676.

ROUPÉ, M. & GUSTAFSSON, M. Judgment and decision-making aspects on the use of virtual reality in volume studies. Open Systems - Proceedings of the 18th International Conference on Computer-Aided Architectural Design Research in Asia, CAADRIA 2013, 2013. 437-446.

SABAH, S., HOSSAIN, I., WEISS, D. & TILLMANN, A. A Fusion of XR Technology and Physical Objects to Increase Citizens Participation in Urban Planning. Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI), 2023. 283-284.

SANCHEZ-SEPULVEDA, M. V., TORRES-KOMPEN, R., FONSECA, D. & FRANQUESA-SANCHEZ, J. 2019. Methodologies of learning served by virtual reality: A case study in urban interventions. Applied Sciences (Switzerland), 9.

SCHAUPPENLEHNER, T., KUGLER, K., MUHAR, A. & BAUTZ, G. 2018. Applications of virtual reality as a tool for communication in participatory planning processes. AGIT-Journal fur Angewandte Geoinformatik, 4, 15-24.

STEWART, L. & LOPEZ, C. Developing Spatial Visualization Skills with Virtual Reality and Hand Tracking. Communications in Computer and Information Science, 2021. 390-398.

TALBI, K., ZERGOUT, I. & SOUAD, A. Analytical study of Virtual reality in Moroccan higher education. Colloquium in Information Science and Technology, CIST, 2023. 503-507.

TRAN, D. H., PHAM, D. T. & HUYNH, P. H. Metaverse Immersive Virtual Reality Enhances Multiple Collaboration in the Construction Design Review Phase. Lecture Notes in Civil Engineering, 2024. 576-583.

VAN LEEUWEN, J., HERMANS, K., JAN QUANJER, A., JYLHÄ, A. & NIJMAN, H. Using virtual reality to increase civic participation in designing public spaces. Proceedings of the European Conference on e-Government, ECEG, 2018. 230-239.

VATS, S. & JOSHI, R. The Impact of Virtual Reality in Education: A Comprehensive Research Study. IFIP Advances in Information and Communication Technology, 2024. 126-136.

WAGEMANN, E. & MARTÍNEZ, J. 2022. IMMERSIVE VIRTUAL REALITY (VR) FOR LEARNING IN ARCHITECTURE. EGA Revista de Expresion Grafica Arquitectonica, 27, 110-123.

WAI YIE, L., LEONG, Y. Z. & LEONG, W. S. Virtual Reality in Education: Case Studies and Applications. IET Conference Proceedings, 2023. 186-187.

WU, W. L., HSU, Y., YANG, Q. F. & CHEN, J. J. 2021. A Spherical Video-Based Immersive Virtual Reality Learning System to Support Landscape Architecture Students' Learning Performance during the COVID-19 Era. LAND, 10

ZHANG, S. & MOORE, A. B. The usability of online geographic virtual reality for urban planning. Lecture Notes in Geoinformation and Cartography, 2014. 225-242.

ZHANG, C., ZENG, W. & LIU, L. G. 2021. UrbanVR: An immersive analytics system for context-aware urban design. COMPUTERS & GRAPHICS-UK, 99, 128-138.

ZHANG, S. & LI, Y. Design of urban environmental planning system based on 3D virtual technology. 4th International Conference on Information Systems and Computer Aided Education, ICISCAE 2021, 2021. Association for Computing Machinery, 2293-2296.

ZUO, H., CHU, W. & YANG, B. Visualization of planning spaces in Virtual Reality. Proceedings of SPIE - The International Society for Optical Engineering, 2023.

Acknowledgments

As a project leader, I extend my deepest gratitude to the entire project team for their dedication and invaluable contributions throughout the duration of this project. Special thanks to Prof. Krystyna Solarek, Prof. Dariusz Gotlib, Prof. Adrianna Czarnecka, Dr ing. Agnieszka Wendland, Msc ing. Monika Piotrkowska, Msc ing. Miłosz Gnat for their expertise, commitment, and tireless efforts in planning, implementing, and evaluating the VR implementations. I would also like to express our appreciation to Warsaw University of Technology IDUB - Excellence Initiative - Research University Dicdiactic Innovations for their support and funding, which made this project possible. Additionally, we acknowledge the cooperation and participation of our students, partners, and stakeholders, whose insights and feedback were instrumental in shaping the outcomes of this project.