Effectiveness of Immersive VR for Reflective Learning in Architectural Technology and Construction Management Education

Liliyana Makarova Jørsfeldt & Meinhardt Thorlund Haahr
University College of Northern Denmark
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Abstract

This study investigates the practice of reflective learning in construction management education by exploring the integration of immersive virtual reality (VR) technologies. Traditional educational approaches often struggle to provide students with immersive and practical experiences that replicate real-world construction scenarios. VR offers an innovative solution by enabling experiential learning in a risk-free environment, supporting the development of critical skills such as decision-making, safety management, and project execution. The research employs a Design-Based Research methodology to design and evaluate interventions that integrate VR into educational frameworks. These interventions are guided by the Reflective Practice-Based Learning (RPL) principle: "Teaching and learning activities are organized as exploration." The study uses qualitative analysis to examine how VR can enhance students' reflection, deepen understanding, and support knowledge transfer and skill development in building design. The findings provide insights into how VR can facilitate meaningful engagement with complex building designs and contribute to the near and far transfer in learning. The immersive VR in education demonstrates significant potential for transforming traditional educational methods. The study's practical implications lie in providing new educational designs that combine technological tools with reflective, practice-oriented learning approaches.

Keywords
Reflective Practice-Based Learning, Immersive Virtual Reality, Architectural Technology and Construction Management Education

Introduction

The use of immersive technologies, particularly Virtual Reality (VR), is now well established in higher education. VR and 3D environments enhance engagement, experiential learning, and knowledge retention, making them powerful tools for both theory and practice. Reviews (Radianti et al., 2020; Wang, 2018) show benefits in spatial learning, motivation, and cognition, while studies in construction education (Le et al., 2015; Lucas et al., 2018) demonstrate VR's effectiveness in supporting experiential learning and efficiency.

By simulating real-world complexity, VR supports both theoretical understanding and professional practice. This aligns closely with the principle of explorative learning (Concept 3 – "Teaching and learning activities are organized as exploration.)(Horn et al., 2020: Brinkmann, 2016; Miettinen, 2000). Here, learning is not about reaching a fixed point. Through reflection, questioning, data collection, and hypothesis building, students are encouraged to interpret situations they experience (Horn et al., 2020) from multiple perspectives. This process, often referred to as abductive learning, supports critical thinking and adaptive problem-solving. Explorative learning is characterized by engaging students in processes of questioning, hypothesis formation, and abductive reasoning, particularly in situations where meaning is uncertain or fragmented. Rather than delivering fixed outcomes, such teaching strategies invite learners to investigate problems from multiple perspectives, collect and interpret data, and develop informed responses through reflective practice. The teacher's role is to design these learning environments in ways that stimulate curiosity, support experimentation, and qualify the reflective dialogue (Laursen, 2017).

Although immersive VR has been widely studied in industrial contexts, there remains a lack of research examining its impact on learning processes and outcomes within higher education settings. Therefore, this study investigates how the use of immersive VR in architectural technology and construction management education (ATCM) can support effective student learning through exploration, reflection, and applied practice. Guided by the RPL principles and Wahlgren's theory of transfer (Wahlgren & Aarkrog, 2012), the study examines how immersive learning environments support knowledge transfer. Near transfer occurs when students apply knowledge in familiar contexts, while far transfer requires adapting learning to novel or unpredictable situations. By involving students in reflective, experience-rich learning tasks, we aim to understand how VR can enhance the ability to connect theory with practice and promote learning that is not only engaging but also meaningful and transferable to real-world construction work.

Research question is posed as follows: *How can the use of immersive VR technologies in ATCM education support effective student learning by promoting near and far transfer through exploration, reflection, and practice, understood within the frameworks of Reflective Practice Learning and Wahlgren's transfer theory?*

Background

This study is grounded in Bjarne Wahlgren's theory of transfer (2013), which emphasizes the conditions under which knowledge and competencies acquired in education are applied in real-world contexts. Wahlgren identifies multiple dimensions of transfer, particularly near transfer (application in familiar contexts) and far transfer (adaptation to novel situations), as critical outcomes of effective learning. His framework outlines twelve key factors influencing transfer, ranging from learner motivation and confidence to instructional design and workplace support.

These dimensions are particularly relevant when immersive technologies like VR are used to support education. VR environments allow for both direct rehearsal of workplace tasks (supporting near transfer) and conceptual exploration that generalizes across contexts (supporting far transfer). This dual potential aligns with Reflective Practice-Based Learning (RPL) (Horn et al., 2020), which frames learning as a process of inquiry, hypothesis-building, and reflection in and on action. The use of VR in construction is grounded in theories of cognitive load reduction, collaboration, and experiential learning. VR's immersive 1:1 environments enhance spatial understanding and reduce abstraction compared to traditional 2D/3D reviews (Haahr, 2023). It fosters interdisciplinary collaboration by providing a shared virtual space, supporting real-time interaction and decision-making aligned with Social BIM principles

(Zaker and Coloma, 2018). Additionally, VR promotes reflective practice through simulation and exploration, supporting knowledge transfer within frameworks like RPL (Zaker and Coloma, 2018). When integrated with BIM, VR further enhances design comprehension, clash detection, and stakeholder engagement (Alizadehsalehi et al 2020) despite challenges like cost and adoption resistance.

Research settings

This study is situated within "De Digitale Dage 2025", a national, cross-institutional educational initiative that bridges professional construction practice and vocational education through digital and collaborative experimentation. The project engages students from multiple institutions – including UCN, AAU, EUC Nord, and Tech College – who work in interdisciplinary teams to develop a building design proposal for the renovation and refurbishment of a public school into a training centre for the North Jutland Police.

Participants assume professional roles such as project manager, BIM coordinator, and sustainability advisor, collaborating across disciplines using industry-standard tools like BIM 360, Revit, Dalux, and LCA Byg. The project's 12-week format and emphasis on teamwork, role-based responsibility, and final presentation offer a highly authentic educational setting. Within this framework, a VR-based learning intervention was introduced to investigate how immersive VR technologies can support exploratory learning, reflective practice, and knowledge transfer.

Methodology: Design-Based Research (DBR) Approach

To explore and develop educational practices grounded in real-life contexts, this study employs a Design-Based Research (DBR) methodology. DBR is well-suited for the dual aim of generating both practical interventions and theoretical insights within complex educational settings. Rooted in pragmatism (Maxcy, 2003), DBR embraces flexible, iterative, and context-sensitive inquiry, closely aligned with both RPL and Wahlgren's transfer theory (2013).

As described by Ann Brown (1992) and Anderson and Shattuck (2012), DBR supports the creation of educational innovations that respond to actual learner needs, while simultaneously contributing to broader theoretical development. The project was structured around four iterative DBR phases, tailored to the educational context and timeline of "De Digitale Dage".

Phase 1: Contextual and Theoretical Foundation. This phase focused on building a foundation for the intervention, including reviewing relevant literature in Design-Based Research, transfer of learning (Wahlgren, 2013), and RPL, mapping the technological and pedagogical environment of "De Digitale Dage", and identifying key competencies and tasks where a VR intervention could meaningfully enhance learning and reflection.

Phase 2: Design of the VR Learning Intervention. Based on the initial analysis, a VR-based module was developed. The design was built to do three things: first, to give students practice with realistic construction tasks and decisions; second, to encourage creative thinking, open exploration, and thoughtful discussion; and third, to help students use their learning in the given case and in future construction practice. The design also followed Mingfong et al.'s (2010) four effectiveness criteria: a structured framework, effective use of VR features, accurate domain knowledge, and attention to the learning context's needs.

A VR laboratory was established and equipped with four Meta Quest 2 headsets and one Meta Quest 3 headset, providing students access to high-quality standalone VR head-mounted displays (HMDs). The laboratory utilized Autodesk XR Workshop, a commercial software solution that facilitates the seamless transfer of building designs from Revit into a virtual environment. Autodesk XR Workshop is a multi-user VR platform specifically designed to support collaboration within the architecture, engineering, and construction (AEC) sectors. The platform enables users to explore building designs at a 1:1 scale within an immersive virtual environment, fostering collaboration, discussion, and reflection on spatial configurations and design decisions in real-time.

Phase 3: Implementation in "De Digitale Dage". The intervention was implemented with three student teams (A, B, C). The VR module was integrated into their collaborative work process as they progressed through design, coordination, and construction planning tasks (Table 1). Each session began with a brief onboarding that covered how to put on the VR headset and launch the software. Once students were in-headset and the application was running, the instructor (one of the authors) provided real-time support and ongoing guidance while students explored. Halfway through each session, the instructor paused the activity to ask students to reflect on their VR experience and how it could be used in other situations in their studies and in their future jobs in building construction.

Data collection was qualitative and conducted through participatory observation, guided by a structured observation protocol and focus group interviews, which captured students' reflections on their use of VR. These approach was explicitly designed to align with the RPL framework and Wahlgren's transfer theory, particularly focusing on how students engage in meaning-making, collaborative problem-solving, and practical application of knowledge.

Table 1: Data collection

Category	Session (Group A)	Session (Group B)	Session (Group C)
Duration of Session	~45 minutes	~10 minutes	~45 minutes
Students and Backgrounds	6 ATCM (4th semester), EQF 6 1 Energy Design, EQF 7 1 Construction Management, EQF 7	2 ATCM (4th semester), EQF 6 1 Electrician, EQF 3/4	2 ATCM (4th semester), EQF 6
Theme of Session	Exploring possibilities with VR Review of initial proposal	Recording VR experience for presentation Design review of team's model	Exploring possibilities with VR Design review of team's model
Data Collected	• Observation: 30–35 min • Interview: 13 min 19 sec • VR video (student): 7 min 58 sec • VR video (teacher): 7 min 30 sec	• Observation: 10 min • VR video (student): 5 min 34 sec • VR video (teacher): 5 min 20 sec	• Observation: 25–30 min • Interview: 29 min 31 sec • VR video (student): 15 min 33 sec • VR video (teacher): 7 min 30 sec

Phase 4: Analysis and Reflection. In the final phase, collected data were analyzed through thematic coding (Saunders et al., 2023) and interpretive analysis, focusing on: Evidence of near and far transfer; Manifestations of exploratory learning and abductive reasoning; Students' capacity to reflect on their learning process and relate it to professional practice. Findings were interpreted considering the underlying theoretical frameworks and used to refine the intervention. This phase also supported broader conclusions about the effectiveness of immersive learning environments in educational contexts.

Limitations

The study has several limitations. First, it rests on a single, short-term educational event, which makes it difficult to assess far transfer. The sample comprises only thirteen students, and the VR sessions occurred in a controlled laboratory setting, limiting generalizability to typical classroom or workplace conditions. Finally, the instructor's dual role as author and facilitator could be a source of bias (Saunders et al., 2023).

Results and findings

In this section, we present the results of the analysis of the executed educational program. The data were collected in 3 sessions, and the main results are presented in Table 2. As shown, students mostly demonstrated near transfer. They applied VR insights to familiar tasks, for example by identifying construction errors: "*that's the house, and it's not built correctly*." Far transfer was rarer. It appeared in Group C, where students experimented with model changes: "what if we make the wall thicker? When the wall becomes thicker, you suddenly get another solution". This observation shows the evidence of how skills could be used in future contexts.

Table 2: Results and findings

Theme	Session (Group A)	Session (Group B)	Session (Group C)
Duration of Session	~45 minutes	~10 minutes	~45 minutes
General Understanding	Some students lacked clarity about planning and purpose. Unclear on how VR connected to their learning tasks.	Similar confusion about planning; did not fully grasp what was expected during the VR activity.	Same issues as S2. Students questioned the purpose and relevance of VR activities.
Digital Skills & Tool Use	Unfamiliarity with VR tools caused hesitation. Some students had not previously used a VR headset.	Reported lack of familiarity with VR and digital coordination tools.	Some students lacked access or had trouble navigating technical requirements.
Exploratory Learning (RPL Pr. 3)	Explored possibilities for how to use VR but felt lost without clearer learning goals.	Mentioned wanting more direction for how to engage in learning via VR.	Engaged in the activity but lacked a sense of direction or educational value.
Transfer of Knowledge	Some evidence of near transfer in applying VR learning to digital models.	Minimal signs of applying learning beyond the session.	Students applied technical skills directly to the case and discussed how they could use their competencies in future contexts.
Collaboration	Collaboration was mixed; some relied on peers, others struggled due to unclear group roles.	Group dynamics less effective; students found teamwork fragmented.	Same as S2, but some noted attempts to help each other understand the task.

Discussion

Students entered the VR sessions with diverse educational and professional backgrounds, influencing how they interpreted tasks and engaged with the technology. This diversity, while beneficial for interdisciplinary learning, also created confusion when instructions or objectives were unclear. A lack of shared understanding often reduces focus and engagement. As one participant expressed: "Some students come directly from high school and don't know what we're referring to when we discuss certain things. In those cases, VR allows us to point and say: *that's the house, and it's not built correctly*."

Many students had limited prior experience with BIM and VR tools. This gap created initial barriers in navigation and understanding the digital workflow. These findings emphasize the importance of early onboarding and digital preparation to enable effective learning transfer, as discussed by Wahlgren (2013).

Some students demonstrated exploratory learning through trial-and-error and model revision. As one participant noted, "…I've been playing around with it these last two days and gained a lot of experience just by testing the program – what can it do, what can't it do…" However, the lack of structured guidance hindered their ability to connect such experimentation to broader learning goals. Support for abductive reasoning and reflective framing is therefore essential to maximize VR's potential as a tool for meaningful exploration

As shown in findings, evidence of near transfer was present when students applied insights gained in VR to immediate design tasks. Far transfer has been observed in session C, and was limited in session B. These results can point to that structured reflection and instructor support are crucial to enable deep, transferable learning outcomes, consistent with Wahlgren's model.

Collaboration outcomes varied. Effective peer learning occurred in groups with clear task distribution and communication. In less structured groups, unclear roles and weak interaction limited knowledge exchange. Clear team roles and guided collaboration strategies are recommended to enhance social learning. Students across sessions expressed a clear need for stronger instructional support.

Importantly, the findings suggest that instructor presence within the VR environment is also crucial. In session B, for example, extensive guidance was needed to help students navigate tasks effectively. This indicates that active instructor involvement during VR experiences is essential to maintain focus on learning goals and support both near and far knowledge transfer.

Conclusion

These findings highlight the importance of designing immersive learning activities with structured goals, clear facilitation, and preparatory digital training. VR can effectively bridge theory and practice in construction education, but its success depends on didactic integration, reflective support, and inclusive collaboration.

Further studies should investigate the long-term impact of VR learning on real-world application, the role of structured reflection tools in enhancing transfer, and how immersive technologies shape professional identity in construction education. Additionally, more research is needed on the role of instructor training and equity in access to digital tools.

References

Aarkrog, V., & Wahlgren, B. (2012). *Transfer: kompetence i en professionel sammenhæng*. Aarhus Universitetsforlag.

Alizadehsalehi, S., Hadavi, A., & Huang, J. C. (2020). From BIM to extended reality in AEC industry. *Automation in Construction, 116* (103254), 1–13.

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher,* 41(1), 16–25.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, 2(2), 141–178.

Brinkmann, S. (2016). *John Dewey: en introduktion* Hans Reitzel.

Haahr, M. T. (2023). Multi-user virtual reality based design review of students construction designs. In C. Park, F. P. Rahimian, N. Dawood, A. Pedro, L. Dongmin, R. Hussain, & M. Soltani (Eds.), *Digitalization in Construction: Recent trends and advances* Routledge. https://doi.org/10.1201/9781003408949-1

Horn, L. H., Jensen, C. G., Kjærgaard, T., Sørensen, I. M., Valbak-Andersen, C., Bundgaard, S. B., & Lukassen, N. B. (2020). *Hvidbog om refleksiv praksislæring.*

Laursen, M. H. (2017). *Abduktiv undervisning og læring*. Hans Reitzel.

Le, Q. T., Pedro, A., & Park, C. S. (2015). A social virtual reality based construction safety education system for experiential learning. *Journal of Intelligent & Robotic Systems, 79*, 487–506.

Lucas, J. (2018). Student perceptions and initial response to using virtual reality for construction education. In T.Sulbaran. *54th ASC Annual International Conference Proceedings (281–288)*. Associated Schools of Construction. http://ascpro0.ascweb.org/archives/cd/2018/paper/CERT101002018.pdf

Maxcy, S. J. (2003). Pragmatic Threads in Mixed Method Research in the Social Sciences: The Search for Multiple Modes of Inquiry and the End of the Philosophy of Formalism. In A. Tashakkori, & C. Teddlie (Eds.), *Handbook of Mixed Methods in the Social and Behavioural Sciences* (pp. 51–89). Sage.

Messner, J., Yerrapathruni, S., Baratta, A., & Whisker, V. (2003). Using virtual reality to improve construction engineering education. Paper presented at the *2003 Annual Conference*. https://doi.org/10.18260/1-2--11970

Miettinen, R. (2000). The concept of experiential learning and John Dewey's theory of reflective thought and action. *International Journal of Lifelong Education*, 19(1), 54–72.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education, 147*, 103778.

Saunders, C. H., Sierpe, A., von Plessen, C., Kennedy, A. M., Leviton, L. C., Bernstein, S. L., Goldwag, J., King, J. R., Marx, C. M., Pogue, J. A., Saunders, R. K., Van Citters, A., Yen, R. W., Elwyn, G., & Leyenaar, J. K. (2023). Practical thematic analysis: A guide for multidisciplinary health services research teams engaging in qualitative analysis. *BMJ*, 2023, 381. https://doi.org/10.1136/bmj-2022-074256

Wahlgren, B. (2013). *Transfer i VEU: Tolv faktorer der sikrer, at man anvender det, man lærer*.

Wang, P., Wu, P., Wang, J., Chi, H., & Wang, X. (2018a). A critical review of the use of virtual reality in construction engineering education and training. *International Journal of Environmental Research and Public Health, 15*(6), 1204.

Zaker, R., & Coloma, E. (2018). Virtual reality-integrated workflow in BIM-enabled projects collaboration and design review: a case study. *Visualization in Engineering, 6*, 1–15.