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Immersive Virtual Reality Improves Vocational Students' Industry-Based Building Material Design Skills

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ABSTRACT

Although VR has been widely introduced in vocational and engineering education, its empirical contribution to strengthening industry-based design skills in building construction learning remains limited. Most previous studies have emphasized VR as a visualization tool, while its role in supporting simulation-based design experimentation is still underexplored. The rapid advancement of immersive technology has reshaped vocational education, emphasizing the need for effective learning strategies to enhance industry-based design skills. Virtual Reality (VR) offers an immersive, interactive environment that bridges academic learning and industry requirements. This study aims to the effectiveness of VR simulation media in building construction for improving design skills. A quasi-experimental pretest–posttest design was used involving 84 students from the Civil Engineering and Planning Education Study Program, Yogyakarta State University, divided into experimental and control groups of 42 students each. Data were collected through observation, tests, and portfolio assessments based on VR simulation activities, and analyzed using a t-test. The results show that the use of VR-based building construction simulation media in construction design courses was effective in enhancing students' design competencies, which was confirmed by the t-test analysis results (sig. < 0.05). These findings are significant because they show that VR simulation can function not only as an immersive visualization medium, but also as a pedagogical strategy for supporting design experimentation and developing construction design competencies aligned with industry needs.

Keywords: Building Construction, Design Skill, Immersive, Virtual Reality, Vocational Education.

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INTRODUCTION

The rapid development of immersive technology has transformed the paradigm of vocational education by providing interactive, learner-centered, and practice-oriented learning environments that can support the development of vocational design skills (Kim et al., 2025). In vocational education, students are expected to develop occupationally relevant competencies that integrate conceptual knowledge, procedural skills, technical accuracy, problem-solving ability, and the capacity to transfer knowledge, skills, and professional attitudes between educational and workplace contexts (Schaap et al., 2012). In the construction sector, these competencies are reflected in students' ability to understand building components, interpret spatial relationships, translate design concepts into accurate technical drawings, evaluate construction feasibility, identify potential design problems, and communicate design ideas in accordance with professional and industry practices (Kandi et al., 2020). Therefore, industry-based building construction design skills in this study are defined as students' ability to generate, visualize, evaluate, and refine building construction designs by applying technical construction knowledge, spatial reasoning, accuracy, and problem-solving processes relevant to construction workplace standards. Within the context of vocational education in the construction sector, mastering design skills that align with the needs of the world of work is a fundamental competency, enabling graduates to compete effectively in the global job market (Daryono et al., 2023; Jacobs, 2019; Oroh et al., 2023). This skill includes not only a theoretical understanding of building structures but also practical skills for transforming concepts into functional, technical, and precise building designs. However, these industry-based design skills are not yet comprehensively developed among vocational students.

Many students still experience difficulties in visualizing three-dimensional building structures, understanding the relationship between structural elements, estimating scale and proportion, and converting conceptual ideas into accurate technical construction designs. Preliminary data were collected from 84 students enrolled in the Building Construction Design course in the Civil Engineering and Planning Education Study Program at Yogyakarta State University, Yogyakarta, Indonesia. The results showed that the students' average pretest score for design skills was 50.79 out of 100, which was below the minimum competency criterion of 75.00. More specifically, only 9 students (10.71%) achieved the expected competency level, whereas 75 students (89.29%) had not yet met the required standard. The portfolio assessment also indicated that students' lowest performance appeared in spatial visualization and design accuracy. The average score for spatial visualization was 58.21, followed by evaluates technical accuracy at 60.47, functional aesthetics at 59.36, and 3) structural feasibility 62.18, and design communication at 66.52. Classroom observation further revealed that 63.33% of students had difficulty interpreting the spatial relationship between beams, columns, slabs, and walls when presented through 2D drawings, while 47.78% showed errors in estimating scale and proportion in their initial design outputs. These findings indicate that students' design skills do not yet fully represent the competencies expected in industry-oriented construction design practices. This condition creates a pedagogical problem: vocational students are required to master applied and industry-based design skills, but the learning environment has not fully provided authentic, interactive, and spatially rich experiences that support the development of such skills.

Conventional learning methods that rely on two-dimensional (2D) representations and limited use of software such as CAD are often unable to facilitate deep spatial understanding and an accurate sense of scale for users (Hartman et al., 2006; Tiwari et al., 2024a; Totuk et al., 2025). The limitations of visual representation in these media make it difficult for users to visualize complex three-dimensional (3D) objects and understand the interdependence between components of structural elements in building construction (Basham, 2006). This approach, which tends to be abstract, is still not able to replicate the complexity of complex building construction modeling, thus triggering a gap between theory and practice in the field (Tiwari et al., 2024b). This limitation was also reflected in the initial learning condition, where 57 of 84 students, or 67.86%, reported that conventional 2D drawings were insufficient to help them understand the actual form, scale, and spatial configuration of building components. In addition, 54 students, or 64.29%, stated that they needed a more interactive medium to explore building models before developing their final design portfolios. In modern construction education and industry practice, transitional digital tools such as Building Information Modeling (BIM), three-dimensional modeling, and augmented reality have also been introduced to improve visualization, coordination, and design communication. Nevertheless, these tools do not always provide a fully immersive, embodied, and interactive learning experience in which students can directly explore construction objects at scale, manipulate design elements, and experience spatial relationships as if they were present in the construction environment. Thus, while CAD, BIM, and AR contribute to digital construction learning, they remain insufficient when the instructional goal is to strengthen students' experiential understanding and design experimentation in an immersive construction context.

Virtual Reality (VR) simulation technology is proposed as an innovative pedagogical instrument capable of creating a realistic, interactive, and immersive instructional environment (Gómez-Cambronero et al., 2023; Hendra Jaya et al., 2025). VR allows users to engage in hands-on design experiments and building construction exploration without the risk of work accidents or physical limitations due to limited access when visiting a building construction directly (Gómez-Cambronero et al., 2023; Nasri et al., 2024; Smirnova et al., 2020). From a pedagogical perspective, VR supports experiential learning in vocational education because it enables students to learn through direct interaction, observation, manipulation, reflection, and revision of design objects in a simulated construction environment. From a cognitive perspective, VR may improve design skills by strengthening spatial visualization, reducing cognitive distance between abstract drawings and real-scale objects, supporting mental rotation of structural components, and helping students detect inconsistencies between design concepts and construction logic. Through VR simulations, users can manipulate design models at full scale that significantly strengthen spatial knowledge, increase active engagement, and minimize technical errors during the learning and training process (Gómez-Cambronero et al., 2023; Hendra Jaya et al., 2025). For example, in the preliminary portfolio analysis, common technical errors included inaccurate column-beam alignment, inappropriate wall openings, inconsistent scale representation, and incomplete integration between structural and architectural elements. These types of errors can be reduced when students are able to inspect construction components in an immersive environment, compare design alternatives, and revise their design decisions based on spatial feedback from the VR simulation. In this sense, the reduction of technical errors is not assumed as an automatic effect of VR, but is explained through the mechanism by which immersive visualization allows students to identify misalignment, proportion errors, component conflicts, and inappropriate spatial arrangements before producing the final design output.

The conceptual framework of this study bridges vocational pedagogy and immersive technology by positioning VR simulation media as a learning intervention that transforms abstract construction design learning into an experiential, interactive, and industry-oriented design process. In this framework, vocational education provides the competency target, namely industry-based building construction design skills, while VR provides the technological learning environment that supports visualization, experimentation, evaluation, and refinement of design outputs. Therefore, VR is not treated merely as a digital visualization tool but as a pedagogical medium that enables students to engage in authentic design practice through simulation-based learning.

Although the integration of VR in learning is beginning to spread, the literature specifically examining the improvement of industry-based design skills in vocational education through quasi-experimental designs remains limited. Previous research has examined the effectiveness of VR in technical training more broadly (Mulders et al., 2024; Refdinal et al., 2023). However, these studies have not sufficiently explained how VR contributes specifically to industry-based building construction design skills, especially in relation to spatial reasoning, construction component interpretation, design experimentation, and portfolio-based design outcomes. Furthermore, limited studies have tested VR simulation media using a quasi-experimental pretest–posttest design involving control and experimental groups in building construction design courses. As a result, stronger empirical evidence is needed to determine whether VR-based construction simulation media can significantly improve vocational students' design competencies compared with conventional learning approaches.

The novelty of this study lies in its empirical examination of VR simulation media as a pedagogical intervention for improving industry-based building construction design skills among vocational students. Unlike previous studies that mainly position VR as a visualization or technical training tool, this study emphasizes VR as a simulation-based design learning medium that supports design experimentation, spatial reasoning, and the development of construction design portfolios. Accordingly, this study is guided by the following research question: Does the use of VR simulation media significantly improve vocational students' industry-based building construction design skills compared with conventional learning? The research objective is to examine the effectiveness of VR simulation media in improving students' design skills in building construction design learning. The hypothesis tested in this study is that students who learn using VR simulation media will demonstrate significantly higher improvement in building construction design skills than students who learn through conventional instructional media. By addressing this question, the study is expected to contribute theoretically to the integration of vocational pedagogy and immersive learning technology, and practically to the development of innovative learning media for construction design education.

METHOD

The research employed a quantitative approach with an experimental design. Specifically, it used a quasi-experimental nonequivalent control group design. The experimental framework is illustrated through the following model (Sugiyono, 2017) :

Experimental Group	O1	X	O2
Control Group	O3		O4

Figure 1. Model Experiment

Description:

O1 & O3 : Pre-Test (measuring the initial design capability)

O2 & O4 : Post-Test (measures skill acquisition after intervention) X Treatment with VR media (experimental group)

The research subjects were students in the Civil Engineering and Planning Education study program, Faculty of Engineering, Yogyakarta State University, enrolled in a building construction course. Ethical clearance was obtained from the Research Ethics Committee of the DRPM UNY, and informed consent was obtained from 84 study participants. Safety protocols were also implemented to ensure student well-being during the VR simulation activities.

Students were randomly assigned to either the experimental or control group to ensure baseline comparability and to minimize selection bias. Each group consisted of 42 participants, and random assignment replaced purposive sampling to maintain methodological rigor appropriate for a quasi-experimental design.

Table 1. Criteria Inclusion and Exclusion

No.	Groups	Number of Participants
1	Control	42
2	Experiment	42

Data is collected through three main instruments designed to measure work-based design skills. First, a pre-posttest was used to measure students' cognitive abilities in building construction theory and spatial visualization. The pre-post test instruments were validated by experts and demonstrated good internal consistency (Cronbach's alpha = 0.83). Second, structured observation sheets are used to measure students' involvement and behavior during the building design process using VR simulation media. Third, the design capability portfolio is assessed using a rubric that aligns with the standards of the world of work and evaluates technical accuracy, functional aesthetics, and structural feasibility. Inter-rater reliability for portfolio assessment was calculated using Cohen's kappa ($\kappa = 0.77$), ensuring consistency between evaluators. The VR simulation media consisted of Oculus Quest 2 headsets and Unity 3D-based custom software developed for building construction exploration, allowing interactive manipulation of structural components and real-time feedback on design skills.

The initial stage of research in each group begins with administering a pre-test to assess students' initial abilities. Several components of design skills were included in the pre-test instruments. The pre-test results served as the initial reference for designing a learning approach that incorporates VR-based simulation media in building construction instruction. Upon completion of the entire learning sequence, both groups were administered a post-test to evaluate the extent of improvement in their building construction design skills.

In its implementation, the control group applied a collaborative learning model to complete construction projects conventionally (studio-based and CAD software). Instead, the experimental group used VR simulations of building construction to implement immersive collaborative learning, allowing students to explore the building model in real time and validate the design's integrity. Throughout the learning activities, observations were carried out in a structured manner to examine the progress of students' design abilities, both individually and collaboratively within groups. The intervention spanned 3 weeks with two 100-minute sessions per week.

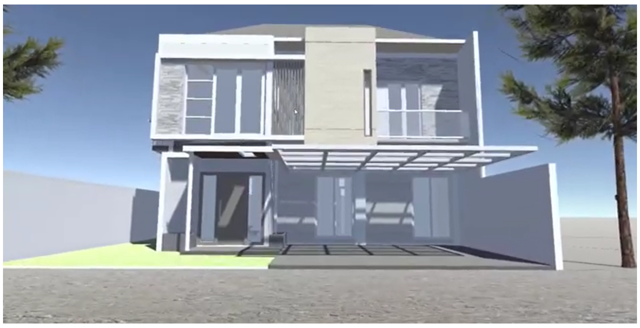

Figure 2. Building Construction Design

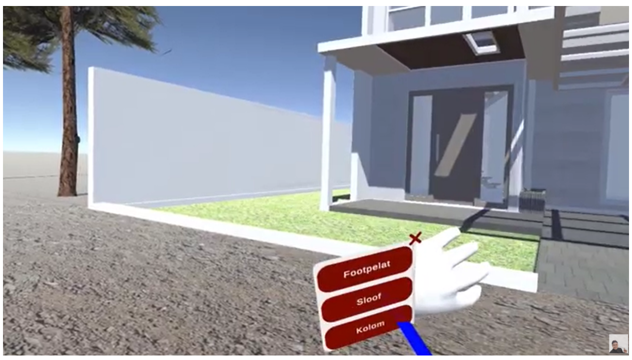

Figure 3. Building Construction VR Simulation Media

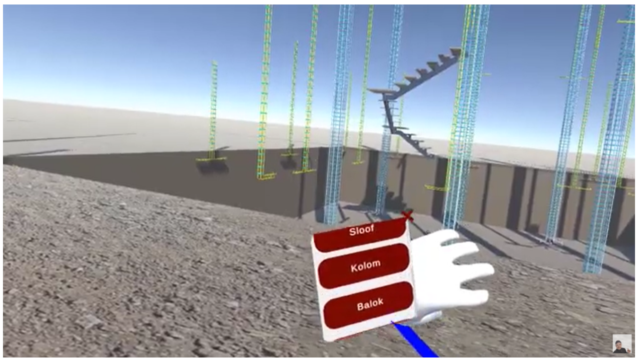

Figure 4. Details of Repetition Design in Building Construction VR

Overall, the learning activities were integrated with VR-based building construction simulation media to illustrate its effectiveness in enhancing students' competencies. In the final stage, project outputs are produced as a portfolio of building construction design results, which will be used as material for further study and in-depth evaluation.

The quantitative data were systematically processed in SPSS using several stages of inferential analysis. The first step is to conduct prerequisite tests to ensure the data are valid before hypothesis testing. After the prerequisite assumptions are met, the analysis proceeds with an effectiveness test. The test was designed to examine whether there was a statistically significant difference in the average post-test scores between the experimental group using VR-based construction media and the control group using conventional instruction. This careful design, together with expert validation of instruments and high inter-rater reliability for portfolio assessment, ensures that the findings reflect true differences in students' industry-based building construction design skills rather than measurement or subjective bias.

RESULTS & DISCUSSION

Result

The aim of this study is to examine the effectiveness of VR-based construction simulation media in enhancing design skills. The initial stage of the study involved administering a pre-test to both the control and experimental groups. This pre-test was conducted using an initial task-based approach to assess students' levels of understanding and skills in building design and construction. The assessed competencies included drawing skills, identifying material requirements, and developing construction work schedules.

The pre-test data obtained from both the control and experimental groups described the participants' initial competence in several aspects of design skills. These aspects included creativity, comprehension of building construction design principles, communication skills, teamwork abilities, technical knowledge, and project management skills. To provide a clear baseline comparison, pre-test scores were separated by group. The control group had a mean pre-test score of 34.50, while the experimental group had a mean of 34.90. An independent-samples t-test confirmed that there was no statistically significant difference between the control and experimental groups at pre-test, indicating that the groups were equivalent in baseline design skill prior to the intervention. The pre-test data are presented below.

Table 2. Pre-Test Design Skills by Group

Group	N	Mean	Median	Std. Deviation	Min	Max	Variance
Control	42	34.50	35.00	5.21	23	44	28.09
Experiment	42	34.90	35.00	5.41	24	47	28.41

Based on the table presented, the control and experimental groups obtained an average design skill score of 34.70, with a minimum score of 23 out of a possible 47. When converted into a percentage, the pre-test achievement level for design skills was 47.78%. This indicates that students' initial understanding and competence in building design and construction-including drawing skills, identifying material requirements, and preparing construction schedules-were still relatively low. These findings became the basis for implementing an experimental intervention using VR-based construction simulation media in the experimental group to enhance students' design skills (Laal & Laal, 2012; N.I.P. Pratama et al., 2022).

Pre-requisite tests using normality tests (Kolmogorov-Smirnov) and homogeneity tests are required before post-tests are carried out in the control and experimental groups. The normality test was conducted to examine whether the initial data followed a normal distribution. The data are considered normally distributed when the significance value exceeds 0.05 (sig. > 0.05). Based on the analysis results, the design skill component was normally distributed, with p-value = 0.200 > 0.05, as shown below in the table.

Table 3. Technology Distribution Across the 35 Included Studies

Name	Valid		Kolmogorov-Smirnov		
	N	Percent	Stat	Sig.	Df
Design Skills	84	100	.112	.200	84

Subsequently, a homogeneity test was performed to determine whether the data from the control and experimental groups were homogeneous. The data are considered homogeneous when the significance value is greater than 0.05 (sig. > 0.05). The results showed that the design skill components in both the control and experimental groups were homogeneous, with a significance value of 0.368 > 0.05. After confirming that the data were normally and homogeneously distributed, an observation was conducted on the implementation of VR simulation media for building construction in the experimental group. After confirming baseline equivalence, normality, and homogeneity, the VR intervention was applied only to the experimental group.

Discussion

This study measures the development of design skills through VR simulation media for building construction, including drawing skills, the ability to identify material needs, and the ability to compile a schedule. While the Results section presented raw outcomes, this Discussion section critically synthesizes the findings in the context of prior research, theory, and international literature. Through the application of VR-based building construction simulation media, the improvement of each component of design skills in producing building construction designs can be identified. Based on the observations, the results indicated the ability to draw, identify material needs, and prepare a schedule using VR simulation media for building construction, as presented in the following table.

Table 4. Results of Observation of the Process of Improving Design Ability

No	Component	Description
1	Creativity	The use of VR simulation media in building construction learning encourages all participants to observe various examples of building design directly through virtual simulations. After the observation phase, participants generated a range of creative solutions to address problems through discussion and experimentation. The ideas produced are then presented to obtain suggestions and feedback from other participants until a final construction design is obtained to be used as a final project or portfolio. The discussion, experimentation, and presentation processes following the use of VR media demonstrated an improvement in participants' creativity.
2	Understanding of building construction design principles	Participants' understanding of building construction design principles has developed better. The increase was seen during the discussion process and the exchange of opinions between participants in learning activities. In addition, the ability to understand design principles also increases when participants provide responses and answers to questions asked by other participants.
3	Communication skills	The use of building construction VR simulation media provides an opportunity for all participants to try and explore building design virtually. During the activity, participants were actively involved in communication through the submission of ideas, opinions, and ideas. Discussion and presentation activities after the use of VR media showed an increase in participants' communication skills throughout the learning process.
4	Collaboration capabilities	In the implementation of learning, all participants are actively involved in discussions so that their participation in working together to complete the final project increases. Participants' collaboration abilities were also enhanced through the activities of developing construction designs and presenting their outcomes, and implementing trials using VR simulation media for building construction.
5	Technical knowledge	Learning activities accompanied by active discussions help participants improve their technical understanding related to the initial knowledge of the project being worked on. During the learning process, participants exchanged opinions and actively

No	Component	Description
		participated in discussions when making presentations after using building construction VR simulation media.
6	Project management skills	The project management skills possessed by the participants in completing tasks show good development. Tasks can be completed according to the target because participants are able to estimate the time needed from the discussion stage to the presentation. In addition, the use of VR media helps participants develop a time schedule to support the completion of the final design project, so that participants' project management skills are improved.

Based on the observations, the use of VR simulation media contributed to improvements in creativity, understanding of building construction design principles, communication skills, collaboration capabilities, technical knowledge, and project management skills. It should be noted that these qualitative observations were not analyzed with a formal coding or thematic analysis, which limits systematic verification. Future research could adopt structured coding protocols, frequency counts, or thematic analyses to strengthen the reliability of qualitative claims. These results are consistent with the study conducted by Pratama, which indicates that the use of simulation media helps participants understand new material more quickly, facilitates trial processes, and reduces the risk of failure (Damayanti et al., 2025; Shiratuddin et al., 2024).

In addition to the t-test results, effect sizes (Cohen's d) were calculated to complement statistical significance. The control group showed a moderate effect size ($d = 1.61$), while the experimental group had a very large effect size ($d = 2.44$), indicating the VR-based intervention had a substantial practical impact on design skills. Critically synthesizing these findings with international literature, this study aligns with Radianti et al. (2020) and Merchant et al. (2014), who found that immersive technologies improve spatial understanding, engagement, and procedural skill acquisition in engineering and architecture education. However, this study extends these findings by providing empirical evidence specifically for vocational education students in building construction, demonstrating not only individual learning gains but also measurable improvements in collaborative problem-solving and project management skills, which were less emphasized in prior work. In addition, the use of learning to design with VR simulation media stimulates participants to actively collaborate and think critically by identifying all risks they will face, thereby minimizing mistakes (Husamah et al., 2025; Imaniar Purbasari, 2023; Norhasyimah Hamzah et al., 2024).

Futhermore, unlike previous research that focused on subjective engagement and perceptions, this study quantitatively confirms the VR effect on design skills through pre-posttests and large effect sizes. While many previous research used small-scale simulations or lab tasks, this study applied VR to full project cycles, including material identification, scheduling, and portfolio development, offering practical implications for real world vocational education. The findings align with prior research indicating that simulation-based learning accelerates comprehension and reduces errors (Damayanti et al., 2025; Shiratuddin et al., 2024). This study demonstrates that VR supports both individual and collaborative learning in design skills, identifying material requirements, and developing construction work schedules, expanding its pedagogical utility and adding novelty to findings from previous research. Despite these promising results, several limitations should be acknowledged. First, the novelty effect of VR may have temporarily increased motivation and engagement. Second, the sample size (n = 84) is relatively small, limiting generalizability. Third, the cost and accessibility of VR hardware may hinder broader implementation. Fourth, some participants experienced mild simulator sickness, which could have affected performance.

During the observation process, the ability of almost all participants in the experimental group to develop design skills increased. The observation results describe the implementation of VR-based learning in building construction as a means of supporting participants in enhancing these skills. The classroom improvement process has been outlined in detail for each component involved. These findings are considered novel and may serve as a reference as well as a foundation for further research in training within the construction and manufacturing industries. Besides the process of developing participants' competencies, through the analysis of different tests (t-tests) in the control group and the experimental group, post-tests were then carried out. The post-test was carried out to assess whether the implementation of VR-based construction learning media effectively improved design skills. The analysis of the data yielded the following results.

Table 5. Results of Differential Test Analysis

Name		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre - Post Control	-24.714	15.274	2.375	-29.474	-19.955	10.487	41	.000
Pair 2	Pre - Post Experiment	-42.405	9.937	1.533	-45.501	-39.308	27.657	41	.000

Based on the results of the t-test comparing the control and experimental groups, overall, it can be concluded that the integration of VR simulation media into building construction design learning effectively enhances students' design skills. These results were obtained through a pre-posttest comparison between the control and experimental groups. The results of the t-test conducted on the control and experimental groups both showed significant results 0.000 (sig. < 0.05) and tcount > ttable (10.487 > 2.019) (N.I.P. Pratama et al., 2026). Meanwhile, the t-test results in the experimental group also showed statistically significant results, $p = 0.000$ (sig. < 0.05) and tcount > ttable (27.657 > 2.019)

(N.I.P. Pratama et al., 2026). The graph below illustrates the percentage improvement in design skills from pre-test to post-test in both the control and experimental groups.

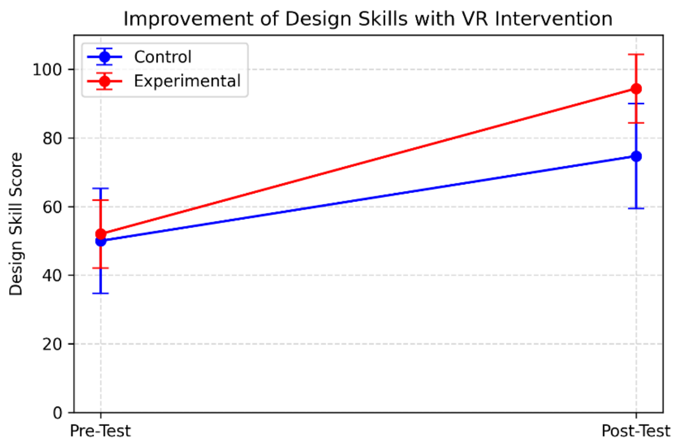

Figure 5. Percentage Increase in Control and Experimental Groups

The figure 5 indicates that the use of VR-based learning in building construction within the experimental group improved students' design skills by 42.22%. The results of this study are very interesting because, based on the results of the analysis of different tests (t-test), they support each other and, in the learning process, can strengthen the increase in these achievements.

Overall, the study demonstrates that VR-based building construction simulation media effectively enhances design skills by identifying material requirements, and developing construction work schedules. The contribution of this study lies in linking empirical findings with broader pedagogical theory, showing that immersive VR can serve both cognitive and social learning purposes in vocational construction education. Future research should integrate systematic qualitative coding, include larger and more diverse samples, and assess long-term retention to fully evaluate the scalability and sustainability of VR interventions. This research also supports research conducted by Hamzah & Imaniar, that through learning based on VR simulation media, it will increase the motivation of participants and their activeness in independent and group learning to gain a more complex understanding (Arika Pusparini et al., 2025; Imaniar Purbasari, 2023; N.I.P. Pratama et al., 2026; Norhasyimah Hamzah et al., 2024). In addition, VR simulation media offers participants a more authentic learning experience that supports experimentation, collaboration, the development of critical thinking skills, and will accelerate the development of students' cognitive and psychomotor abilities (Kartikasari et al., 2023, 2025; Sumandya et al., 2023; Wulandari et al., 2026).

CONCLUSION

The analysis of the research findings shows that VR-based simulation media in building construction design learning is effective in improving students' design skills. This is supported by the t-test results obtained from the experimental class, which indicate a statistically significant difference, with a significance value of p = 0.000 (sig. < 0.05). In addition, the calculated t-value (tcount) of 27.657 is greater than the critical t-value (ttable) of 2.019, confirming that the improvement in students' design skills is statistically significant.

In this study, design skills were developed through the experimental process, using VR simulation media for building construction that are in accordance with industry needs. However, it should be noted that claims regarding alignment with industry requirements are based on learning outcomes in design skills and expert validation results.

The results of this study will make a significant contribution to the use of VR simulation media. By combining VR simulation media with collaborative learning, this study can stimulate the development of users' cognitive and psychomotor abilities. In addition, the findings of this study are highly applicable to contextual and practice-oriented learning in vocational education. Overall, while the findings strongly support the effectiveness of VR for enhancing design skills, further research integrating employer evaluations would strengthen claims regarding direct industry readiness.

REFERENCES

Arika Pusparini, L., Silitonga, L. M., & Senowarsito. (2025). Artificial Intelligent Supported Duolingo: Enhancing Students' Speaking Skills and Reducing Speaking Anxiety in Vocational Education. Jurnal VARIDIKA, 91–112.https://doi.org/10.23917/varidika.v37i1.10431

Basham, K. (2006). The effects of 3-dimensional CADD modeling software on the development of the spatial ability of ninth grade technology discovery students [Doctor of Philosophy, Louisiana State University and Agricultural and Mechanical College]. https://doi.org/10.31390/gradschool_dissertations.875

Damayanti, D. A., Utami, P. D., Sutanto, A. B., Ishartono, N., & Lestari, D. N. (2025). Gamifying Cooperative Learning: The Impact of Team Games Tournament and Wordwall Media on Student Engagement in Elementary Science Education. Jurnal VARIDIKA, 113–130. https://doi.org/10.23917/varidika.v37i2.8986

Daryono, R. W., Ramadhan, M. A., Kholifah, N., Isnantyo, F. D., & Nurtanto, M. (2023). An empirical study to evaluate the student competency of vocational education. International Journal of Evaluation and Research in Education (IJERE), 12(2), 1079. https://doi.org/10.11591/ijere.v12i2.22805

Gómez-Cambronero, Á., Miralles, I., Tonda, A., & Remolar, I. (2023). Immersive Virtual-Reality System for Aircraft Maintenance Education: A Case Study. Applied Sciences, 13(8), 5043. https://doi.org/10.3390/app13085043

Hartman, N., Connolly, P., Gilger, J., & Bertoline, G. (2006). Developing A Virtual Reality Based Spatial Visualization Assessment Instrument. 2006 Annual Conference & Exposition Proceedings, 11.433.1-11.433.19. https://doi.org/10.18260/1-2--122

Hendra Jaya, Muhammad Farid, Sapto Haryoko, M. Mahdinul Bahar, Edy Sabara, & Saharuddin. (2025). Integration of Virtual Reality (VR) technology to enhance practical skills and professionalism in engineering training. World Journal of Advanced Engineering Technology and Sciences, 15(2), 1653–1663. https://doi.org/10.30574/wjaets.2025.15.2.0678

Husamah, H., Rahardjanto, A., Permana, T. I., & Shukri, A. A. M. (2025). Integration of Digital Technologies in Environmental Education: A Systematic Review of Trends, Impacts, and Future Directions. Jurnal VARIDIKA, 30–47. https://doi.org/10.23917/varidika.v37i1.9908

Imaniar Purbasari. (2023). Bamboo Woven Websites for Elementary School Students through Social

Collaborative Learning Approach. Journal of Advanced Research in Applied Sciences and Engineering Technology, 31(1), 315–325. https://doi.org/10.37934/araset.31.1.315325
Jacobs, R. L. (2019). National Occupational Standards. In R. L. Jacobs, Work Analysis in the Knowledge Economy (pp. 113–128). Springer International Publishing. https://doi.org/10.1007/978-3-319-94448-7_8
Kandi, V. R., Castronovo, F., Brittle, P., Mastrolembo Ventura, S., & Nikolic, D. (2020). Assessing the Impact of a Construction Virtual Reality Game on Design Review Skills of Construction Students. Journal of Architectural Engineering, 26(4), 04020035. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000434
Kartikasari, M., Fitriana, L., & Nurhasanah, F. (2023). The special education teachers' ability to develop an integrated learning evaluation of Pancasila student profiles based on local wisdom for special needs students in Indonesia. Kasetsart Journal of Social Sciences, 44(2). https://doi.org/10.34044/j.kjss.2023.44.2.23
Kartikasari, M., Triyanto, Fitriana, L., & Nurhasanah, F. (2025). Using Interactive Teaching Materials to Improve Indonesian Students' Numeracy Skills: A Systematic Literature Review. Jurnal VARIDIKA, 1–13. https://doi.org/10.23917/varidika.v37i1.8336
Kim, J., Yu, S., Detrick, R., & Li, N. (2025). Exploring students' perspectives on Generative AI-assisted academic writing. Education and Information Technologies, 30(1), 1265–1300. https://doi.org/10.1007/s10639-024-12878-7
Laal, M., & Laal, M. (2012). Collaborative learning: What is it? Procedia - Social and Behavioral Sciences, 31, 491–495. https://doi.org/10.1016/j.sbspro.2011.12.092
Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. Computers & Education, 70, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033
Mulders, M., Buchner, J., & Kerres, M. (2024). Virtual Reality in Vocational Training: A Study Demonstrating the Potential of a VR-based Vehicle Painting Simulator for Skills Acquisition in Apprenticeship Training. Technology, Knowledge and Learning, 29(2), 697–712. https://doi.org/10.1007/s10758-022-09630-w
Nasri, M., Narayan, U., Sonbudak, M. F., Simonson, A., Chiu, M., Donati, J., Sivak, M., Kosa, M., & Harteveld, C. (2024). Designing a Virtual Reality Training Apprenticeship for Cold Spray Advanced Manufacturing (Version 1). arXiv. https://doi.org/10.48550/ARXIV.2411.08859
N.I.P. Pratama, G., Triyono, M. B., Hasanah, N., B. Kenzhaliyev, O., N. Kosherbayeva, A., K. Kassymova, G., & Azman, M. N. A. (2022). Development of Construction Engineering Teaching Course by using VR-AR: A Case Study of Polytechnic in Indonesia. International Journal of Interactive Mobile Technologies (iJIM), 16(14), 93–106. https://doi.org/10.3991/ijim.v16i14.30539
N.I.P. Pratama, G., Triyono, M. B., Widodo, S., Kohler, T., Syamsudin, R. N., & Dinata, C. (2026). The Effectiveness of Collaborative Learning with BIM-AR in Improving DesignSkills and Higher-Level Thinking Skills. Journal of Advanced Research Design, 138(1), 192–204. https://doi.org/doi.org/10.37934/ard.138.1.192204
Norhasyimah Hamzah, Normah Zakaria, Arihasnida Ariffin, & Siti Nur Kamariah Rubani. (2024). The Effectiveness of Collaborative Learning in Improving Higher Level Thinking Skills and Reflective Skills. Journal of Advanced Research in Applied Sciences and Engineering Technology, 42(1), 191–198. https://doi.org/10.37934/araset.42.1.191198
Oroh, R. R., Attaufiq, M. M., Daud, M., & Roring, R. F. (2023). Analysis of Vocational Student Performance Criteria on Work Skills Based on Industry Needs: An Analysis for Students' Skill Test Instruments. International Journal of Learning, Teaching and Educational Research, 22(10), 174–189. https://doi.org/10.26803/ijlter.22.10.10
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. https://doi.org/10.1016/j.compedu.2019.103778
Refdinal, R., Adri, J., Prasetya, F., Tasrif, E., & Anwar, M. (2023). Effectiveness of Using Virtual

Reality Media for Students' Knowledge and Practice Skills in Practical Learning. JOIV : International Journal on Informatics Visualization, 7(3), 688–694. https://doi.org/10.30630/joiv.7.3.2060

Schaap, H., Baartman, L., & De Bruijn, E. (2012). Students' Learning Processes during School-Based Learning and Workplace Learning in Vocational Education: A Review. Vocations and Learning, 5(2), 99–117. https://doi.org/10.1007/s12186-011-9069-2

Shiratuddin, M. F., Kok, W. W., & Rai, S. (2024). ViCubeLab-An Integrated Platform Using VR to Visualise and Analyse Road Traffic Conditions. Journal of Advanced Research in Applied Sciences and Engineering Technology, 49(2), 176–186. https://doi.org/10.37934/araset.49.2.176186

Smirnova, A., Zaychenko, I., Bagaeva, I., & Gorshechnikova, P. (2020). Digital technologies in the industry: Application of immersive training technologies in the oil and gas complex. SHS Web of Conferences, 84, 03003. https://doi.org/10.1051/shsconf/20208403003

Sugiyono, P. (2017). Metode penelitian bisnis: Pendekatan kuantitatif, kualitatif, kombinasi, dan R&D (87th ed.). Penerbit CV. Alfabeta. https://opac.perpusnas.go.id/DetailOpac.aspx?id=1084409

Sumandya, I. W., Widana, I. W., Suryawan, I. P. P., Handayani, I. G. A., & Mukminin, A. (2023). Analysis of understanding by design concept of teachers' independence and creativity in developing evaluations of mathematics learning in inclusion schools. Edelweiss Applied Science and Technology, 7(2), 124–135. https://doi.org/10.55214/25768484.v7i2.382

Tiwari, A. S., Bhagat, K. K., & Lampropoulos, G. (2024a). Designing and evaluating an augmented reality system for an engineering drawing course. Smart Learning Environments, 11(1), 1. https://doi.org/10.1186/s40561-023-00289-z

Tiwari, A. S., Bhagat, K. K., & Lampropoulos, G. (2024b). Designing and evaluating an augmented reality system for an engineering drawing course. Smart Learning Environments, 11(1), 1. https://doi.org/10.1186/s40561-023-00289-z

Totuk, O. H., Selvi, Ö., & Akar, S. (2025). Fused filament fabrication in CAD education: A closed-loop approach. International Journal of Mechanical Engineering Education, 53(1), 167–188. https://doi.org/10.1177/03064190231215307

Wulandari, T., Susanti, E., & Hiltrimartin, C. (2026). Students' Perceptions of Augmented Reality Based Student Worksheets on Circle Geometry. Jurnal VARIDIKA. https://doi.org/10.23917/varidika.v38i2.13592