

The Impact of Learning Management through Design Thinking and VR Technology to Enhance the Engineering Drawing Ability of the Second-Year Vocational Students

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Abstract

The purposes of this study were to: 1) compare the engineering drawing ability of the second-year vocational students before and after learning through the traditional approach; 2) compare the engineering drawing ability of the second-year vocational students before and after learning through design thinking and VR technology; and 3) compare the engineering drawing ability of students who learned through the traditional approach with those who learned through design thinking and VR technology. The sample consisted of 72 second-year vocational students in China during the 2025 academic year. Two classes were selected by cluster random sampling. One class (36 students) served as the experimental group and learned through design thinking and VR technology, while the control group (36 students) learned through the traditional approach.

The research instruments included the traditional approach learning management plans, the integrated design thinking and VR technology learning management plans, and an engineering drawing ability assessment. The data were analyzed using the mean, standard deviation, dependent-samples t-test, and independent-samples t-test. The results indicated that: 1) students' engineering drawing ability after learning through the traditional approach was significantly higher than before learning at the .05 level of significance; 2) students' engineering drawing ability after learning through design thinking and VR technology was significantly higher than before learning at the .05 level of significance; and 3) students who learned through design thinking and VR technology achieved significantly higher engineering drawing ability than those who learned through the traditional approach at the .05 level of significance.

Keywords: design thinking, VR technology, engineering drawing ability

1. Introduction

Engineering drawing ability was a fundamental competency in vocational and engineering education, particularly in spatial visualization, technical accuracy, and the correct application of standardized drawing conventions. In engineering education contexts, engineering drawings functioned as a primary medium for representing and communicating technical ideas, supporting both interpretation and collaboration in design-related tasks (Tiwari et al., 2024).

For vocational students, engineering drawing ability was not only regarded as a basic technical skill but also served as a foundational competence that supported subsequent professional learning. In construction- and engineering-related disciplines, technical accuracy in drawing was closely associated with task coordination and collaborative performance, indicating its role as an essential component of instructional quality and skill development (Setiawan et al., 2021).

Previous studies indicated that the traditional engineering drawing approach commonly relied on teacher-centered, highly structured instructional methods, such as step-by-step demonstrations, explicit explanations of drawing standards, and repetitive practice exercises. These instructional practices effectively supported students' acquisition of fundamental drawing knowledge, including projection principles, dimensioning, and standardized conventions, thereby contributing to technical accuracy and procedural correctness (Tumkor & de Vries, 2015; Kadam et al.,

2021).

However, research also suggested that the reliance on two-dimensional representations in the traditional approach could constrain students' understanding of complex spatial relationships, particularly when learning involved abstract geometric forms or intricate components. Several studies have reported that students struggle to mentally transform two-dimensional drawings into accurate three-dimensional representations, which can negatively affect performance on engineering drawing tasks (Martín et al., 2024).

With the advancement of educational technology, VR technology has increasingly been applied in engineering and technical education to support spatial understanding and visualization. VR-based learning environments provided immersive three-dimensional representations that allowed learners to observe objects from multiple perspectives and interact with virtual components, thereby facilitating a clearer perception of spatial relationships. Empirical studies reported that such environments were associated with improvements in spatial ability and drawing-related performance among engineering students (Akkuş & Yüksel, 2022; Yang et al., 2024).

In addition, VR-supported learning was found to reduce the cognitive demands associated with interpreting abstract two-dimensional drawings by externalizing three-dimensional structures into interactive visual experiences. This transformation supported conceptual understanding and promoted more meaningful learning processes in technical subjects (Li et al., 2023; Matovu et al., 2023).

Design thinking was widely adopted as an instructional approach that emphasized learner-centered problem exploration, iterative ideation, and solution refinement through prototyping and testing. Rather than focusing on reproducing predetermined procedures, design thinking encouraged students to engage in reflective inquiry and consider problems from multiple perspectives throughout the learning process (Hehn & Méndez Fernández, 2022).

Empirical studies in engineering and design-related higher education contexts have reported that design thinking supports the development of problem-solving ability, creativity, and reflective thinking, particularly when learners are required to analyze open-ended problems and iteratively refine their solutions (Tu et al., 2018; Guaman-Quintanilla et al., 2023). Moreover, design thinking was found to promote collaborative learning and active engagement, thereby addressing limitations of passive learning environments in the traditional approach (Dukala et al., 2023).

Although previous studies had independently demonstrated the educational benefits of design thinking and VR technology, existing research had largely examined these approaches in isolation. Many studies focused either on the technological effectiveness of immersive environments for improving spatial ability or on the pedagogical outcomes of learner-centered instructional models, without systematically investigating their combined application in engineering drawing instruction.

In particular, empirical evidence regarding the integration of design thinking and VR technology in vocational education contexts remained limited. Given the practical and visualization-intensive nature of engineering drawing tasks, it was necessary to examine how immersive visualization tools and iterative, problem-oriented learning processes could be combined to enhance students' engineering drawing ability. Therefore, this study investigated the effects of learning management through design thinking and VR technology on students' engineering drawing ability, compared with the traditional approach, to provide empirical evidence supporting instructional innovation in vocational engineering drawing education.

1.1 Research Objectives

The objectives of this study were as follows:

To compare students' engineering drawing ability before and after learning through the traditional approach.

To compare students' engineering drawing ability before and after learning through design thinking and VR technology.

To compare students' engineering drawing ability between the group learning through design thinking and VR technology and the group learning through the traditional approach.

1.2 Research Hypotheses

H1: The engineering drawing ability of the second-year vocational students after learning through the traditional approach was higher than before at the .05 level of significance.

H2: The engineering drawing ability of the second-year vocational students after learning through design thinking and VR technology was higher than before at the .05 level of significance.

H3: The engineering drawing ability of the second-year vocational students who learned through design thinking and VR technology thinking was higher than that of students who learned through the traditional approach at the .05 level of significance.

2. Method

2.1 Research Design

This study employed a quasi-experimental research design with a pretest–posttest control group design. The design allowed for the comparison of learning outcomes within groups and between groups while maintaining instructional consistency across the academic semester. The independent variable was the instructional approach, consisting of two conditions: traditional approach and design thinking and VR technology. The dependent variable was students' engineering drawing ability as measured by the standardized test.

2.2 Participants

The sample consisted of 72 second-year vocational students in China during the 2025 academic year. Two intact classes were selected using cluster random sampling to ensure practical feasibility within the school setting. One class, comprising 36 students, served as the experimental group and received learning management through design thinking and VR technology. The other class, also comprising 36 students, served as the control group and received instruction through the traditional approach.

Both groups were taught the same engineering drawing content, and the instructional duration was equivalent. The only difference between the groups was the instructional strategy employed.

2.3 Research Instrument

The research instruments used in this study consisted of three main components: 1) the traditional approach learning management plans, 2) the integrated design thinking and VR technology learning management plans, and 3) the engineering drawing ability assessment.

The traditional approach was teacher-centered and emphasized technical accuracy and standardized procedures in engineering drawing. The instructional characteristics focused on the systematic transmission of knowledge, accuracy control, and repetition. The teaching process followed a fixed instructional sequence: 1) explanation of engineering drawing concepts and standards by the teacher, 2) demonstration of drawing procedures and techniques, 3) student practice under teacher supervision, and 4) correction and reinforcement through immediate feedback. The instructional content covered fundamental topics, including drawing standards, geometric construction, orthographic projection, sectional views, dimensioning, and technical correctness. This approach aimed to ensure that students acquired foundational drawing knowledge and procedural skills. The lesson plan was examined by experts in engineering education, curriculum design, and educational measurement. Content validity was evaluated using the Index of Item-Objective Congruence (IOC), and all items achieved IOC values equal to 1.00.

The learning management system, developed through design thinking and VR technology, integrates VR-supported three-dimensional visualization with a structured design thinking process.

In VR technology, the instructional design emphasized building immersive virtual learning environments to support spatial cognition and engineering drawing practice. The teaching steps of VR Technology consisted of: 1) Design, in which teachers clarified learning objectives and VR-specific goals by identifying engineering drawing concepts that were difficult to understand in two-dimensional formats and translating them into immersive virtual scenarios; 2) Modeling, where learners' sensory experiences and problem-solving behaviors were simulated through interactive scenario scripts and task flows; 3) Implementation, during which VR environments were developed using three-dimensional software and VR platforms, enabling students to interact with virtual objects and complete spatial and drawing-related tasks; 4) Evaluation, which examined learning effectiveness through tests, observation, and learner feedback; and 5) VR Situation Construction, which focused on problem-driven, immersive tasks simulating real-world engineering drawing situations, allowing students to solve spatial problems and apply drawing principles in authentic virtual contexts.

These instructional steps transformed abstract engineering drawing concepts into concrete, interactive learning experiences, thereby enhancing students' spatial understanding and engineering drawing ability.

Regarding design thinking, the instructional process followed a structured, iterative sequence emphasizing problem analysis and solution refinement. The teaching steps of design thinking included: 1) empathizing with the drawing

task by understanding design requirements, functional purposes, and user needs embedded in engineering scenarios; 2) defining the drawing problem by identifying key spatial constraints, projection requirements, and technical standards; 3) ideating alternative drawing solutions by generating and comparing multiple drawing strategies; 4) prototyping by producing preliminary drawing solutions or representations; and 5) testing and refining drawings through feedback, evaluation, and revision. This process encouraged reflective thinking, creativity, and systematic problem-solving in engineering drawing activities.

The learning management through design thinking and VR technology was operationalized through the ESIIT Model, a five-step instructional framework designed to enhance engineering drawing competencies. The implementation step was structured as follows: 1) Empathize Setting: Students engaged with engineering drawing challenges within realistic vocational contexts, using VR to immerse themselves in complex environments to clarify task objectives and constraints. 2) Scenario Problem Framing: Learners leveraged VR's spatial visualization capabilities to deconstruct scenarios, identifying critical projection principles—including orthographic, sectional, and axonometric projections—and technical requirements aligned with Chinese National Standards GB/T 50104-2019 and GB/T 50001-2017. 3) Idea Simulation and Behavioral Modeling: The virtual environment served as a sandbox for design thinking, allowing students to explore alternative drawing strategies and model professional tool usage (Manual/CAD) and drawing behaviors before execution. 4) Interactive Prototyping in VR: This stage bridged the gap between 3D cognition and 2D representation; students manipulated three-dimensional virtual models and observed spatial relationships from multiple viewpoints to validate their drawing logic and the technical correctness of the content. 5) Test and Iterative Evaluation: Utilizing the rubric-based assessment, students engaged in reflective practice and feedback loops regarding line consistency, layout organization, and annotation legibility, continuously refining their drawing products through the iterative nature of design thinking. The learning management plan was developed through instructional design and expert validation. IOC values for all instructional components were equal to 1.00, indicating high content validity.

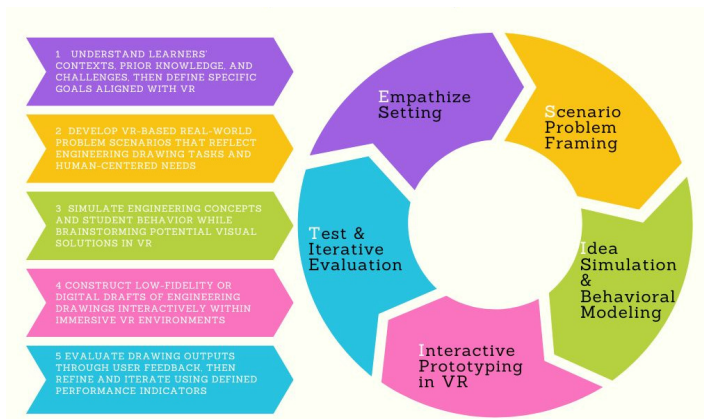


Figure 1. VR Technology and Design Thinking (ESIIT Model)

The engineering drawing ability assessment was developed as a rubric-based instrument to evaluate students' performance across two primary domains: the drawing process and the drawing product. Grounded in Chinese National Standards (GB/T 50104-2019 and GB/T 50001-2017), the rubric comprises six core dimensions: spatial visualization (orthographic, sectional, and axonometric projections), application of drawing standards (line types, symbols, and annotations), content completeness, drawing quality and neatness, interpretation of design requirements, and tool proficiency (Manual/CAD). Each dimension is assessed on a five-point Likert scale ranging from excellent to very poor. The instrument's content validity was confirmed using the Item-Objective Congruence (IOC) method, with all items scoring 1.00, indicating strong alignment with professional engineering expectations.

2.4 Data Collection

Before the instructional intervention, both groups completed the pretest to assess their baseline engineering drawing ability. The control group then received instruction through the traditional approach, which primarily involved teacher explanation, textbook-based examples, and practice exercises.

The experimental group received learning management through design thinking and VR technology. During

instruction, students interacted with three-dimensional virtual models, observed projections dynamically, and engaged in structured problem-solving activities based on the stages of design thinking. Students collaboratively analyzed drawing problems, generated solution ideas, constructed graphical representations, and evaluated their solutions.

After the completion of the instructional period, both groups completed the posttest under the same testing conditions.

2.5 Data Analysis

Descriptive statistics, including mean and standard deviation, were calculated to summarize students' scores. A paired-samples t-test was used to compare pretest and posttest scores within each group in order to determine whether a significant improvement occurred.

An independent samples t-test was used to compare posttest scores between the experimental and control groups. Prior to conducting the independent samples t-test, Levene's Test for Equality of Variances was performed to examine whether the assumption of homogeneity of variance was satisfied.

Levene's test for equality of variances revealed a statistically significant result ($F = 9.21, p = .004$), indicating that the assumption of equal variances between the two groups was violated. Therefore, Welch's t-test was applied for the subsequent between-group comparison.

3. Results

This section presents a comparative analysis of students' engineering drawing abilities by examining differences before and after instruction, as well as between two learning approaches: the traditional method and the integration of Design Thinking with VR technology. Paired-samples t-test was used to compare pretest and posttest scores within each group and independent-samples t-tests was employed to evaluate the posttest scores between the two groups to compare the effectiveness between the approaches. The results clearly reflected students' development and the comparative effectiveness of the instructional methods.

3.1 Comparison of Engineering Drawing Ability Before and After Learning Through the Traditional Approach

A paired-samples t-test was conducted to examine differences in students' engineering drawing ability before and after learning through the traditional approach.

Table 1. Paired Samples t-test for Pretest and Posttest Scores

Traditional	Number of Units (n)	Mean (\bar{X})	Standard Deviation (SD)	Computed t-value (t)	Degrees of Freedom (df)	Sig. (p-value)	Cohen's d
Before	36	16.44	2.903	24.90*	35	< .001	2.84
After	36	20.67	3.225				

Note. $p < .001$.

As shown in Table 1, students' posttest scores ($\bar{X} = 20.67, SD = 3.23$) were significantly higher than their pretest scores ($\bar{X} = 16.44, SD = 2.90$). The difference was statistically significant, $t(35) = 24.90, p < .001$. The effect size was very large (Cohen's $d = 2.84$), indicating that the traditional approach had a substantial impact on students' engineering drawing ability.

3.2 Comparison of Engineering Drawing Ability Before and After Learning Through Design Thinking and VR Technology

A paired-samples t-test was conducted to determine whether students' engineering drawing ability improved after learning through design thinking and VR technology.

Table 2. Paired Samples t-test for Pretest and Posttest Scores

Design Thinking and VR	Number of Units (n)	Mean (\bar{X})	Standard Deviation (SD)	Computed t-value (t)	Degrees of Freedom (df)	Sig. (p-value)	Cohen's d
Before	36	17.17	3.038	22.94*	35	< .001	3.82
After	36	22.86	3.053				

Note. $p < .001$.

Presented in Table 2, students' posttest scores ($\bar{X} = 22.86$, $SD = 3.05$) were significantly higher than their pretest scores ($\bar{X} = 17.17$, $SD = 3.04$). The improvement was statistically significant, $t(35) = 22.94$, $p < .001$. The effect size was extremely large (Cohen's $d = 3.82$), suggesting that design thinking and VR technology had a substantial and meaningful impact on students' engineering drawing ability.

3.3 Comparison of Engineering Drawing Ability Between Traditional Approach and Design Thinking and VR Technology

This section presents a comparison of students' engineering drawing ability between the traditional approach and design thinking and VR technology. Before conducting the between-group comparison, the assumption of homogeneity of variances was examined using Levene's test.

Table 3. Levene's Test for Equality of Variances

F	df1	df2	Sig.
0.047	1	66	.829

The results indicated that the variances were not significantly different between the groups, $F(1, 70) = 0.047$, $p = .829$. Therefore, the assumption of homogeneity of variances was met. An independent-samples t-test was then conducted to compare posttest scores between students who learned through the traditional approach and those who learned through design thinking and VR technology.

Table 4. Comparison of Engineering Drawing Ability Between Learning Management through Traditional Approach and Learning Management through Design Thinking and VR Technology

Learning Management	Number of Units(n)	Mean (\bar{X})	Standard Deviation (SD)	Computed t-value (t)	Degrees of Freedom (df)	Sig. (p-value)	Cohen's d
VR and Design Thinking	36	22.86	3.05	2.96*	70	.002	0.70
Traditional	36	20.67	3.22				

Note. $p < .005$.

As shown in Table 4, students who learned through design thinking and VR technology ($\bar{X} = 22.86$, $SD = 3.05$) scored significantly higher than those who learned through the traditional approach ($\bar{X} = 20.67$, $SD = 3.22$), $t(70) = 2.96$, $p = .004$. The effect size was moderate to large (Cohen's $d = 0.70$), indicating that design thinking and VR technology provided additional benefits beyond the traditional instructional approach.

4. Discussion

4.1 Effects of the Traditional Approach on Engineering Drawing Ability

Regarding the first research objective, the findings confirmed that the traditional instructional approach significantly improved students' engineering drawing ability, particularly in procedural accuracy and adherence to standardized drawing conventions. This outcome aligns with prior studies indicating that teacher-centered, step-by-step instruction effectively supports the acquisition of foundational technical skills in engineering drawing (Tumkor & de Vries, 2015; Kadam et al., 2021).

However, when examined analytically, the improvement observed under the traditional approach appears largely limited to surface-level procedural competence. While students demonstrated greater correctness in applying drawing rules and conventions, the instructional design offered limited opportunities for learners to engage in deeper spatial interpretation or to actively construct three-dimensional mental models from two-dimensional representations. This limitation supports Martín et al. (2024), who argued that conventional drawing instruction often underrepresents the cognitive complexity required for spatial transformation and visualization.

From a theoretical standpoint, these findings suggest that traditional instruction primarily supports the acquisition of procedural knowledge rather than integrated spatial-cognitive development. Engineering drawing ability, when cultivated solely through structured demonstrations and repetition, risks being reduced to a rule-following activity, rather than a cognitively generative process involving spatial reasoning and reflective judgment. This observation highlights an important boundary condition of traditional pedagogy in vocational engineering education: while it is effective for foundational skill formation, it may be insufficient for fostering higher-order spatial cognition required in complex engineering tasks.

4.2 Effects of Design Thinking and VR Technology

Regarding the second research objective, the results indicated that learning management through design thinking and VR technology led to significantly greater improvements in engineering drawing ability. Consistent with prior research, immersive VR environments enhanced learners' spatial visualization by enabling direct interaction with three-dimensional models and allowing observation from multiple perspectives (Akkuş & Yüksel, 2022; Yang et al., 2024).

Nevertheless, this study extends existing literature by demonstrating that the observed learning gains cannot be attributed to immersive visualization alone. While VR externalized spatial information and reduced cognitive load associated with interpreting abstract two-dimensional drawings (Li et al., 2023; Matovu et al., 2023), the integration of design thinking played a critical mediating role in structuring students' cognitive engagement. Through iterative cycles of problem framing, ideation, prototyping, and evaluation, learners were encouraged to reflect on their drawing decisions, test alternative solutions, and refine their work based on feedback.

Theoretically, this finding supports the argument that immersive technologies achieve their pedagogical potential only when embedded within learner-centered instructional frameworks that promote metacognitive regulation and reflective inquiry (Hehn & Méndez Fernández, 2022; Tu et al., 2018). Design thinking functioned not merely as a sequence of activities but as a cognitive scaffold that transformed VR which was a visualization tool into a mechanism for iterative design reasoning. This insight contributes to instructional theory by emphasizing the importance of pedagogical orchestration in technology-enhanced learning environments.

For instructional practice, the integrated learning management through design thinking and VR technology provided a practical and effective instructional model for engineering drawing courses in vocational education. This model supported students in overcoming difficulties in spatial transformation and abstract understanding that commonly existed in the traditional learning environment, which was consistent with evidence showing that virtual reality effectively improved spatial visualization and comprehension in technical drawing education (Miralbes et al., 2023). It strengthened students' hands-on operation ability, problem-solving skills, and mastery of professional drawing standards, which were consistent with the talent training goals of vocational education. The implementation of this model also improved the accuracy, standardization, and overall quality of students' engineering drawing products, and enhanced students' ability to translate three-dimensional spatial cognition into standardized two-dimensional technical drawings. In addition, the integrated approach promoted active learning, reflective thinking, and iterative design practices, which were rarely emphasized in traditional teacher-centered instruction, as supported by research highlighting the role of design thinking in enhancing reflective inquiry and learner engagement (Hehn & Méndez Fernández, 2022). Therefore, this model could be widely applied in engineering drawing, construction drawing, mechanical drawing, and other technical courses in vocational colleges, and provided a replicable paradigm for the pedagogical innovation of technology-integrated vocational education. These results further confirmed the effectiveness of immersive VR in improving practical skills in engineering and technical education (Yang et al., 2024).

4.3 Comparative Effects Between Instructional Approaches

With respect to the third research objective, the findings revealed that students who learned through design thinking and VR technology achieved significantly higher engineering drawing ability than those who learned through the traditional approach. This difference reflects not only a quantitative improvement in performance but also a

qualitative shift in learning outcomes.

While traditional instruction emphasized procedural correctness, the integrated approach supported the development of spatially grounded, reflective, and transferable drawing competence. The immersive VR environment enabled learners to construct robust three-dimensional mental representations, while design thinking facilitated collaborative problem-solving and iterative refinement—elements largely absent in conventional instruction. These results are consistent with Dukala et al. (2023), who highlighted the role of immersive and learner-centered approaches in enhancing conceptual understanding and collaborative learning in engineering education.

Importantly, this comparative analysis suggested that engineering drawing ability should be theorized as a multidimensional construct rather than a unidimensional technical skill. The superiority of the design thinking and VR technology approach underscores the need to align instructional design with the cognitive demands of engineering practice, where spatial reasoning, reflective judgment, and iterative design processes are inseparable. From a theoretical perspective, the findings support a shift away from transmission-oriented models toward integrative learning frameworks that situate technical accuracy within broader spatial-cognitive and design-oriented competencies.

Taken together, the findings support a conceptual framework in which engineering drawing ability is shaped by the interaction between visualization affordances and instructional cognition. Traditional instruction primarily enhances procedural knowledge through structured demonstration and rule-based practice, leading to improved technical accuracy but limited development of higher-order spatial reasoning. In contrast, learning management through design thinking and VR technology operates as a synergistic system that combines immersive three-dimensional visualization with iterative processes of problem framing, reflection, and solution refinement. This interaction enables learners to translate three-dimensional mental models into standardized two-dimensional engineering drawings. Accordingly, engineering drawing ability is conceptualized as an integrated cognitive competence grounded in spatial visualization, reflective problem-solving, and iterative design reasoning (Akkuş & Yüksel Arslan, 2022; Tu et al., 2018; Kraus et al., 2022).

5. Conclusion

The findings of this study demonstrated that both the traditional approach and learning management through design thinking and VR technology contributed to the development of students' engineering drawing ability, albeit through different instructional mechanisms. The traditional approach effectively supported the acquisition of foundational knowledge, procedural accuracy, and understanding of standardized drawing conventions through structured, teacher-centered instruction. These outcomes were particularly relevant to establishing essential technical skills in introductory engineering drawing education.

In contrast, learning management through design thinking and VR technology resulted in significantly higher engineering drawing ability. The immersive visualization provided by VR technology enhanced students' spatial understanding, while design thinking fostered reflective problem-solving, creativity, and iterative improvement through learner-centered processes. The combined implementation of these approaches offered richer cognitive and experiential learning opportunities than traditional instruction alone.

Importantly, the results indicated that engineering drawing ability should be conceptualized as an integrated cognitive competence rather than merely a procedural drafting skill. This competence encompasses spatial visualization, reflective problem-solving, and the ability to translate three-dimensional understanding into accurate two-dimensional technical representations. In this study, learning management through design thinking and VR technology was more effective than the traditional approach in supporting vocational students' integrated competence. Nevertheless, the findings should be interpreted in light of the study's limitations regarding sample characteristics and instructional duration.

6. Recommendations

Based on the findings of this study, learning management through design thinking and VR technology should be implemented in engineering drawing courses, particularly in vocational education contexts. Using VR environments to present three-dimensional models and spatial structures can enhance students' understanding of complex geometric relationships and support the development of engineering drawing ability as an integrated cognitive competence. To ensure effective implementation, systematic professional development for teachers is essential, with

a focus on the pedagogical application of VR technology, the design of VR-based learning activities, and the integration of design thinking processes into engineering drawing instruction. Strengthening teachers' competencies in these areas is likely to enhance instructional quality and facilitate the successful adoption of learner-centered and visualization-oriented learning environments.

While the present study demonstrated the effectiveness of this integrated instructional approach, further research is required to extend and refine these findings. Future studies should investigate the effects of different virtual reality modalities, such as immersive, augmented, and mixed reality, on engineering drawing ability across diverse educational contexts. In addition, broader learning outcomes, including creativity, collaborative skills, learning motivation, and long-term retention, should be examined to provide a more comprehensive understanding of the sustained educational impact and generalizability of learning management through design thinking and VR technology.

References

- Akkuş, A., & Yüksel Arslan, P. (2022). The Effects of Augmented Reality in the Technical Drawing Course on Engineering Students' Spatial Ability and Academic Achievement. *Journal of Learning and Teaching in Digital Age*, 7(2), 160-174. <https://doi.org/10.53850/joltida.1020075>
- Dukala, K., Pyrkosz Pacyna, J., & Czarny, R. (2023). DTMethod: A new evidence based Design Thinking methodology for effective teamwork. *Sustainability*, 15(5), Article 4187. <https://doi.org/10.3390/su15054187>
- Guaman-Quintanilla, S., Chiluiza, K., Everaert, P., & Valcke, M. (2023). Impact of design thinking in higher education: A multi-case study in engineering. *International Journal of Technology and Design Education*, 33(1), 217-240. <https://doi.org/10.1007/s10798-021-09724-z>
- Hehn, J. N., & Méndez Fernández, D. (2022). Combining design thinking and software requirements engineering to create human-centered software-intensive systems. *Design thinking for software engineering: Creating human-oriented software-intensive products and services* (pp. 11-60). Springer International Publishing. https://doi.org/10.1007/978-3-030-90594-1_2
- Kadam, K., Mishra, S., Deep, A., & Iyer, S. (2021). Enhancing engineering drawing skills via fostering mental rotation processes. *European Journal of Engineering Education*, 46(5), 796-812. <https://doi.org/10.1080/03043797.2021.1920891>
- Li, W., Liu, X., Zhang, Q., Zhou, B., & Wang, B. (2023). VR Enhanced Cognitive Learning: Method, Framework, and Application. *Applied Sciences*, 13(8), Article 4756. <https://doi.org/10.3390/app13084756>
- Martín Erro, A., Martínez Muneta, M. L., & Rodríguez Sevillano, Á. A. (2024). Exploring freehand drawing skills of engineering students as a support of visualization. *Education Sciences*, 14(6), 641. <https://doi.org/10.3390/educsci14060641>
- Matovu, H., Ungu, D. A. K., Won, M., Tsai, C.-C., Treagust, D. F., Mocerino, M., & Tasker, R. (2023). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, 59(2), 205-244. <https://doi.org/10.1080/03057267.2022.2082680>
- Miralbes, R., Ranz, D., Gomez, J. A., & Diago, L. (2023). Implementation of virtual reality for teaching in technical drawing. In F. Cavas-Martínez, M. D. Marín Granados, R. Mirálbes Buil, & O. D. de-Cózar-Macías (Eds.), *Advances in design engineering III. INGEGRAF 2022* (pp. 831-838). Springer. https://doi.org/10.1007/9783-031-20325-1_63
- Setiawan, A. H., Takaoka, R., Tamrin, A., Roemintoyo, M., E. S., & Trianingsih, L. (2021). Contribution of collaborative skill toward construction drawing skill for developing vocational course. *Open Engineering*, 11(1), 755-771. <https://doi.org/10.1515/eng-2021-0073>
- Tiwari, A. S., Bhagat, K. K., & Lampropoulos, G. (2024). Designing and evaluating an augmented reality system for an engineering drawing course. *Smart Learning Environments*, 11(1), Article 1. <https://doi.org/10.1186/s40561-023-00289-z>
- Tu, J.-C., Liu, L.-X., & Wu, K.-Y. (2018). Study on the learning effectiveness of Stanford Design Thinking in integrated design education. *Sustainability*, 10(8), Article 2649. <https://doi.org/10.3390/su10082649>
- Tumkor, S., & de Vries, R. H. (2015). Enhancing spatial visualization skills in engineering drawing courses. *2015 ASEE Annual Conference & Exposition, Seattle, Washington, USA*. <https://doi.org/10.18260/p.24001>

- Weaver, M. B., Hilton, E. C., & Linsey, J. S. (2024). Insights into designers' sketching: A study of predictors of sketching behavior in design. *Design Science*, 10, Article e26. <https://doi.org/10.1017/dsj.2024.20>
- Wongtapha, P., & Songkram, N. (2019). Development of blended learning model with Design Thinking and TRIZ principles to enhance engineering problem solving skills of engineering undergraduate students. *Frontiers in Engineering Innovation Research*, 17(2), 37-47. (In Thai)
- Yang, C., Zhang, J., Hu, Y., Yang, X., Chen, M., Shan, M., & Li, L. (2024). The impact of virtual reality on practical skills for students in science and engineering education: A meta-analysis. *International Journal of STEM Education*, 11(1), 1-25. <https://doi.org/10.1186/s40594-024-00487-2>

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No additional data are available.

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