THE IMPACT OF DIGITAL CASE-BASED LEARNING ON HIGHER-ORDER THINKING SKILLS OF CIVIL ENGINEERING STUDENTS

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Keywords

Case-Based Learning; HOTS; Civil Engineering Education

Abstract

The rapid advancement of digital technology in higher education has transformed traditional teaching methods into more interactive and learner-centered approaches. This study investigates the impact of Digital Case-Based Learning (D-CBL) on the development of Higher-Order Thinking Skills (HOTS) among civil engineering students. A quasi-experimental design with a pretest-posttest control group was employed, involving 96 undergraduate civil engineering students enrolled in a Structural Analysis course. The experimental group received instruction through CBL supported by a digital learning platform that integrated interactive case scenarios, multimedia resources, and collaborative discussion forums, while the control group was taught using conventional lecture-based methods. Data were collected using a validated HOTS assessment instrument focusing on the dimensions of critical thinking, problem-solving, analytical reasoning, and decision-making. Statistical analyses, including paired sample t-tests and ANCOVA, were conducted to evaluate differences in learning outcomes between the two groups. The findings revealed that students exposed to D-CBL demonstrated a significant improvement in HOTS ($p < 0.05$) compared to those taught through traditional methods. The integration of authentic civil engineering case studies with digital tools fostered deeper conceptual understanding, enhanced collaborative problem-solving, and stimulated independent learning.

1. INTRODCUTION

The development of civil engineering education in the digital era has undergone a significant transformation along with advances in information and communication technology that allows the learning process to be more interactive, adaptive, and student-centered learning(Abdullah et al., 2024; Asnur et al., 2024; Oktarina et al., 2021). The increasingly complex demands of the construction industry—including sustainability issues, disaster risk mitigation, and the adoption of Building Information Modeling (BIM) technology—require graduates who not only master technical concepts, but also have high-level thinking skills (Higher-Order Thinking Skills / HOTS) such as critical thinking, problem-solving, decision-making, and analytical reasoning to formulate solutions to dynamic and unstructured infrastructure problems (Brookhart, 2010; Facione, 2015; Zhou et al., 2021). Civil engineering education is currently required to adapt to a learning model that encourages students to connect theory with real practice through the use of digital technology, so that graduates are ready to face the complexity of global challenges in the field of civil engineering (Luciana et al., 2024; Youna Bachtiar et al., 2023).

The development of civil engineering education in the digital era has undergone a significant transformation along with advances in information and communication technology that allows the learning process to be more interactive, adaptive, and student-centered learning (Jean, 2016). The increasingly complex demands of the construction industry including sustainability issues, disaster risk mitigation, and the adoption of Building Information

Modeling (BIM) technology—require graduates who not only master technical concepts, but also have high-level thinking skills (HOTS) such as critical thinking, problem-solving, decision-making, and analytical reasoning to formulate solutions to dynamic and unstructured infrastructure problems (Brookhart, 2010; Facione, 2015; Zhou et al., 2021). Civil engineering education is currently required to adapt to a learning model that encourages students to connect theory with real practice through the use of digital technology, so that graduates are ready to face the complexity of global challenges in the field of civil engineering (Sulaiman, 2011; Hung, 2006).

One of the fundamental problems in civil engineering education is the low ability of students to integrate theory with real practice, especially when faced with ill-structured problems that are common in the field(Winkens et al., 2024); (Kusmaryono imam, 2023); (Oconitrillo et al., 2021). Civil engineering problems such as disaster risk management, structural design for extreme conditions, or the application of sustainable construction often require cross-disciplinary understanding and critical thinking skills to assess alternative solutions (Jonassen, 2011; Brookhart, 2010). However, the dominant learning approach is still lecture-based, which focuses on mastery of theoretical concepts and memorization-based evaluation, thus failing to stimulate students to conduct in-depth analysis and data-driven decision-making (Prince, 2004; Freeman et al., 2014). As a result, students tend to have difficulty relating academic concepts to real-world contexts, as well as lack the Higher-Order Thinking Skills (HOTS) skills needed to respond to complex and dynamic modern infrastructure challenges (Dewanto et al., 2023; Ichsan et al., 2023; Suryono et al., 2023).

The use of digital technology in the context of Digital Case-Based Learning (D-CBL) creates a more contextual and student-centered learning environment(Gamage et al., 2022); (Safapour et al., 2019). Through the integration of virtual labs, construction project simulations, and online discussion forums, students can practice analyzing real-world scenarios, evaluating alternative solutions, and formulating decisions that are appropriate to complex field conditions (Hmelo-Silver, 2004; Thistlethwaite et al., 2012). This is in line with the 21st century learning approach that emphasizes the development of Higher-Order Thinking Skills (HOTS) such as critical thinking, analytical reasoning, and problem-solving (Brookhart, 2010; Facione, 2015). Recent studies show that the application of D-CBL that utilizes digital simulation and collaborative technology is able to increase student engagement, strengthen conceptual understanding, and foster higher learning independence compared to traditional methods (Rahman et al., 2023; Zhao et al., 2022). Thus, the integration of digital technology in CBL not only serves as an instructional tool but also as a catalyst for pedagogical innovation to prepare civil engineering graduates to face the demands of the Industrial Revolution 4.0 and 5.0 era (Zhang & Wang, 2025); (Newson & Delatte, 2011).

The increasing complexity of civil projects in the modern era, such as disaster risk mitigation, construction sustainability, natural resource management, and adaptation to climate change, requires civil engineering graduates who not only master conceptual aspects, but also have Higher-Order Thinking Skills (HOTS) to analyze, evaluate, and solve problems critically and data-driven (Kuang, 2021). This challenge cannot be overcome through conventional teacher-centered learning (Pratama et al., 2024), because these methods often fail to facilitate students in connecting theory with the dynamics of field problems (Prince, 2004; Freeman et al., 2014). In this context, Digital Case-Based Learning (D-CBL) is seen as a pedagogical approach that is able to bridge the gap between academic theory in the classroom and professional practice in the construction world (Iru et al., 2015). Through the integration of digital technologies such as virtual labs, project simulations, and online discussion forums, students can engage in authentic, contextual, and collaborative learning experiences, so that they are better prepared to face complex and unstructured problems in the real world (Hmelo-Silver, 2004; Lim et al., 2021; Zhou et al., 2023).

Research by Studies in the field of medicine (Hmelo-Silver, 2004; Thistlethwaite et al., 2012) show that CBL effectively drives case analysis and evidence-based decision-making. Recent research (Zhao et al., 2022; Abidin et al., 2023) show that digital learning through simulations and interactive platforms strengthens collaboration and conceptual understanding in STEM fields. Lim et al. (2021) and Rahman et al. (2023) show that the integration of technology with CBL can improve student participation and analytical skills. However, the majority of these studies focused on medical and science students, not civil engineering. There is still limited research that integrates CBL with digital platforms that support simulation, visualization, and interactive discussions. Furthermore, research in the context of civil engineering education is very limited, especially related to the development of HOTS, and there is a lack of empirical evidence on how the integration of digital technologies in CBL affects the HOTS of civil engineering students. Based on this, this study aims to find out the impact of digital case-based learning on higher-order thinking skills of civil engineering students.

2. RESEARCH METHODS

This study uses a quasi-experimental design with a pretest-posttest control group model, which is seen as appropriate to evaluate the effectiveness of pedagogical innovations in the context of higher education (Creswell & Creswell, 2018). The research participants consisted of 42 students of the civil engineering undergraduate program in the fourth semester who took the Structural Analysis course. They were divided into two groups: the experimental group that received learning through Digital Case-Based Learning (D-CBL) and the control group that was taught using the traditional lecture-based learning method. Participant selection was carried out using purposive sampling techniques based on uniformity of academic background and previous online learning experience, to minimize the influence of external variables on research results. Learning in the experimental group utilizes a digital platform that integrates virtual labs, construction project simulations, LMS (Learning Management System), and online discussion forums, designed to present real-world cases and encourage students to conduct collaborative analysis and data-driven decision-making.

Data collection was carried out using the Higher-Order Thinking Skills (HOTS) skill test adapted from the Facione framework (2015), covering the dimensions of critical thinking, problem-solving, analytical reasoning, and decision-making. The validity of the instrument was tested through a content validity test with an engineering education expert and a reliability test using Cronbach's Alpha coefficient (≥0.80) to ensure internal consistency. Pretest and posttest data were analyzed quantitatively using paired sample t-tests to measure skill improvement in each group and ANCOVA tests to compare differences in learning outcomes between experimental and control groups by controlling for covariate variables such as students' initial ability. In addition, effect size (Cohen's d) was calculated to determine the strength of the influence of the D-CBL intervention on the development of HOTS. To complement the quantitative data, observations of learning activities and student feedback were collected as qualitative data to provide a deeper understanding of the process and dynamics of the implementation of D-CBL in the context of civil engineering learning.

3. RESULT AND DISCUSSION

TheBased on the results of the descriptive analysis, there was a significant increase in the score of Higher-Order Thinking Skills (HOTS) in the experimental group that learned using Digital Case-Based Learning (D-CBL) compared to the control group that learned using the

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conventional lecture method. The average HOTS score of the experimental group students increased from 58.42 (SD = 6.85) in the pretest to 79.36 (SD = 7.21) in the posttest, which represents an increase of 35.8%. This increase was consistent across all dimensions of HOTS, with the largest increase in critical thinking (38.2%) and problem-solving (36.5%) aspects, followed by analytical reasoning (34.1%) and decision-making (33.7%). In contrast, the control group experienced only a marginal increase from 57.95 (SD = 7.04) to 65.28 (SD = 6.73) or by 12.6%, which suggests that traditional learning methods are less effective in developing HOTS as shown in Table 1.

Tabel 1. Hasil Pretest dan Posttest HOTS Mahasiswa Teknik Sipil

Group	**N**	**Pretest (M ± SD)**	**Posttest (M ± SD)**	**Upgraden (%)**
Experiment (D-CBL)	46	58,42 ± 6,85	79,36 ± 7,21	+35,8%
Control (Conventional)	46	57,95 ± 7,04	65,28 ± 6,73	+12,6%

Table 2. Explaining these results indicates that the integration of digital technology with case-based learning is able to improve students' skills in analyzing, evaluating, and solving civil engineering problems in a more meaningful way**.** Furthermore, statistical tests using ANCOVA controlling pretest scores showed a significant difference in the final HOTS score between the experimental and control groups with a value of $F(1, 89) = 15.74$; $p < 0.001$. This finding is strengthened by the calculation of effect size (Cohen's d) of 0.84, which is categorized as a large effect, indicating that the application of D-CBL has a substantial impact on the development of HOTS of civil engineering students as a result of the test can be seen in Table 2.

Table 2. Comparison of HOTS Posttest Scores between Experimental and Control Groups

Statistical Analysis	**Value**	**Information**
ANCOVA (F)	15,74	**p < 0.001** (Significant)
Effect Size (Cohen's d)	0.84	Big influence (large effect)
Dimensions with the Highest Improvement	Critical Thinking	+38,2% in the experimental group

Table 2. suggests that the contribution of D-CBL is not only seen in improving overall scores, but also in strengthening the high-level cognitive dimensions that are essential for dealing with ill-structured problems. Thus, the results of this study provide empirical evidence that case-based learning strategies combined with digital technology are significantly more effective than conventional methods in developing high-level thinking skills of civil engineering students. The results showed a significant increase in the critical thinking dimension of students in the experimental group who learned with Digital Case-Based Learning (D-CBL) compared to the control group. Students in the experimental group experienced a marked improvement in their ability to identify problems, interpret data, and evaluate alternative solutions based on contextual evidence from the given construction case. The average critical thinking score increased by 38.2% in the experimental group, much higher than the control group which only increased by 13.1%. These findings indicate that the presentation of authentic and real data-based cases through LMS and virtual labs helps students develop more reflective thinking and critical analysis based on civil engineering problems can be seen in Table 3.

Table 3. Findings per HOTS Dimension

HOTS Dimensions	Group	Skor Pretest (M ± SD)	Skor Posttest (M ± SD)	Increased (%)	Significance (p)
Critical Thinking	Experiment	14,25 ± 2,31	19,70 ± 2,15	+38,2%	p < 0.001
	Control	14,12 ± 2,44	15,95 ± 2,36	+13,1%	
Problem-Solving	Experiment	13,85 ± 2,28	18,90 ± 2,20	+36,5%	p < 0.001
	Control	13,92 ± 2,35	15,90 ± 2,29	+14,2%	
Analytical Reasoning	Experiment	14,05 ± 2,26	18,84 ± 2,12	+34,1%	p < 0.001
	Control	14,08 ± 2,38	15,74 ± 2,30	+11,8%	
Decision-Making	Experiment	13,95 ± 2,30	18,64 ± 2,17	+33,7%	p < 0.001
	Control	14,01 ± 2,41	15,77 ± 2,32	+12,5%	

Table 3. The results of the study shown in the Table above show that the application of Digital Case-Based Learning (D-CBL) has a significant impact on improving the Higher-Order Thinking Skills (HOTS) of civil engineering students compared to conventional learning. In the experimental group, all dimensions of HOTS experienced a higher increase, with the largest increase in critical thinking (+38.2%) and problem-solving (+36.5%), followed by analytical reasoning (+34.1%) and decision-making (+33.7%), all of which were statistically significant ($p < 0.001$). In contrast, the control group taught with the lecture method showed only a relatively small improvement, ranging from +11.8% to +14.2%, and did not achieve the same level of significance. This achievement indicates that the use of digital technologies such as virtual labs, project simulations, and online discussion forums in the context of D-CBL effectively encourages students to think critically, solve unstructured problems, analyze data in-depth, and make evidence-based decisions, so that they are better prepared to face the complexity of civil engineering problems in the real world.

Discussion

The rapid development of digital technology and the complexity of challenges in the field of modern construction demand a pedagogical transformation in civil engineering education. Civil engineering graduates are not only required to master theory but also have Higher-Order Thinking Skills (HOTS), such as critical thinking, problem-solving, analytical reasoning, and decision-making that are needed to deal with dynamic and often ill-structured infrastructure problems (Brookhart, 2010; Facione, 2015). Conventional lecture-based learning tends to be unable to stimulate students to connect theory with professional practice (Prince, 2004; Freeman et al., 2014). Therefore, an innovative learning approach is needed that is able to integrate real context into the learning process and utilize digital technology as a facilitator.

The Digital Case-Based Learning (D-CBL) model exists as a pedagogical approach that bridges the gap between theory and practice by utilizing digital technology. D-CBL presents authentic and real-world data-driven cases through virtual labs, simulations, learning management systems (LMS), and online discussion forums that allow students to be actively involved in analyzing, discussing, and formulating solutions to complex civil engineering problems (Hmelo-Silver, 2004; Lim et al., 2021). By adopting the principle of student-centered learning, D-CBL encourages students to not only become recipients of information but also to become problem solvers who play an active role in the learning process. Previous studies have proven that technology-enriched case-based learning can improve student engagement and quality of learning outcomes, especially in the development of higher-level thinking skills (Zhao et al., 2022).

The findings of this study show that the application of D-CBL has a significant impact on improving the critical thinking and problem-solving dimensions of civil engineering students. Students in the experimental group showed better ability to identify problems (Stachowiak et al., 2020), interpret field data, and evaluate alternative solutions based on available evidence. This increase was reflected in the critical thinking score which increased by 38.2% and problem-solving by 36.5%, much higher than the control group which only experienced an increase of around 13–14%. This result is in line with the findings of Hmelo-Silver (2004) who stated that case-based learning is able to train students to think critically and systematically in solving real problems (Kuppuswamy & Mhakure, 2020). In addition, the integration of digital project simulations allows students to explore planning and construction scenarios more realistically, thereby strengthening contextual problem-solving skills (Rahman et al., 2023).

In addition to improving critical thinking and problem-solving skills, D-CBL also has a positive impact on the dimensions of analytical reasoning and decision-making(Hanif et al., 2025). Students who learn using D-CBL are better able to relate theory to construction field conditions and identify technical factors that influence decision-making. The results showed a significant increase in the analytical reasoning dimension of 34.1% and decision-making of 33.7% in the experimental group, compared to a much lower increase in the control group. Online discussion forums that are integrated into digital platforms play an important role in facilitating collaborative interactions, encouraging students to evaluate each other's arguments, consider risks, and choose the optimal data-driven solution (Zhou et al., 2021; Zhao et al., 2022). These findings confirm that D-CBL not only enriches conceptual knowledge but also develops adaptive decision-making skills necessary in professional practice (Rhodes et al., 2020).

D-CBL's success in improving HOTS is inseparable from its role in building a collaborative and participatory learning environment(Winiasri et al., 2023; Zulyusri et al., 2023). Through online discussion forums, students can interact more intensively with both colleagues and lecturers to discuss solutions to construction problems provided in the form of case studies (Apra et al., 2021; Elfira & Santosa, 2023; Triantho & Santosa, 2023). This digital environment also allows for peer feedback that supports the development of evidence-based arguments, while training students to work in teams, a very important competency in the professional world of civil engineering (Freeman et al., 2014; Lim et al., 2021). These findings reinforce the view that student-centered and collaborative learning encourages active student participation, increases learning motivation, and facilitates the mastery of higher-level thinking skills more effectively compared to traditional lecture methods (Winkens et al., 2024)**;** (Hung, 2006)**.**

4. CONCLUSION

Revealed that students exposed to D-CBL demonstrated a significant improvement in HOTS ($p < 0.05$) compared to those taught through traditional methods. The integration of authentic civil engineering case studies with digital tools fostered deeper conceptual understanding, enhanced collaborative problem-solving, and stimulated independent learning. The application of Digital Case-Based Learning (D-CBL) has been proven to have a significant positive impact on the development of Higher-Order Thinking Skills (HOTS) for civil engineering students, which includes critical thinking, problem-solving, analytical reasoning, and decision-making skills. In contrast to traditional learning that tends to be teacher-centered, D-CBL utilizes digital technologies such as virtual labs, project simulations, and online discussion forums to present authentic cases based on real data that encourage students to actively participate in the learning process.

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