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From Virtual Laboratory to Classroom: The Effectiveness of Computer-Based Interactive Simulation on Architecture Students' Achievement Motivation

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Abstract
Motivation is one of the fundamental factors guiding human performance. Architecture students often lack adequate motivation to engage with theoretical and technical coursework. This quasi-experimental study assessed the effect of a computer-based simulator on achievement motivation in the Building Structures course. Conducted from September 2022 to January 2023 at Urmia Azad University (Iran), the study employed a pretest–posttest control-group design (n=52) with participants matched on prior grades and divided into experimental (simulation-based instruction) and control (traditional instruction) groups (n=26 each). Data collection comprised the Hermans' Achievement Motivation Questionnaire (HAMQ) and systematic behavioral observations. Analysis used ANCOVA, controlling for baseline motivation. Results demonstrated a significant effect of simulation on motivation ($p<.05$; $\eta^2=.66$), with the experimental group exhibiting a substantial pretest–posttest increase compared to minimal change in controls. The experimental group also achieved significantly higher end-of-term exam scores ($p<.001$). Qualitative observations indicated that the computer simulator, acting as a virtual laboratory environment and engaging the visual, auditory, and tactile senses, reduced the limitations in understanding complex concepts and enhanced the students' problem-solving skills and motivation. However, challenges such as technical complexity, implementation costs, the need for appropriate infrastructure, difficulties in assessment, and the potential diminishment of the instructor's role were also identified, requiring comprehensive planning to address them. In addition, combining simulation with traditional methods of teaching fundamental concepts may lead to improved effectiveness in the instruction of practical skills. The results of this study suggest using computer simulators as a complementary tool in the instruction of architecture courses.

Keywords
Achievement Motivation, Building Structures, Computer Simulation, Architectural Education. Hermans Achievement Motivation Questionnaire

Introduction

Architectural education has long grappled with balancing theoretical, technical, and practical dimensions. Over recent decades, a growing student preference for practical courses—particularly design studios—and a waning focus on theoretical and technical foundations in building construction have become systemic issues in the field. This imbalance not only reduces students' motivation to engage with technical subjects but also perpetuates a gap between theoretical knowledge and real-world design problem-solving. In this context, achievement motivation—the driving force of learning—plays a crucial role in translating abstract concepts into practical skills (Haru, 2023). Individuals with similar aptitudes often exhibit divergent academic outcomes, primarily due to differences in motivational factors (Urhahne & Wijnia, 2023). Notably, empirical evidence suggests that enhancing academic motivation by up to 45% can significantly boost design creativity. This finding underscores the urgent need to revisit traditional instructional approaches (Sadeghi et al., 2022; Saif, 2023).

Digital technologies—particularly computer simulations—have emerged as transformative educational strategies. By creating interactive virtual laboratories, these tools enable learners to explore complex phenomena such as structural behavior, heat transfer, and acoustics dynamically (Kumar & Janardhan, 2023). For example, Carnegie Mellon University's 3D spatial simulator and Aalto University's lighting-design platform demonstrate this technology's potential to enrich architectural curricula. Yet, research on their effects on architecture students' achievement motivation remains contradictory. Critics argue that simulations cannot substitute hands-on experiences and may undermine tactile understanding of materials, potentially distancing students from the subtleties of design and construction (Anindita et al., 2022). In contrast, proponents contend that virtual environments support safe trial-and-error, deepen spatial concept comprehension, and increase engagement with abstract ideas (Czermainski de Oliveira et al., 2024).

These contradictions, combined with the scarcity of research in developing countries—particularly in Iran—highlight a significant gap in the literature. Most prior studies have focused predominantly on cognitive outcomes (such as final exam grades), whereas psychological factors like the need for achievement and persistence in problem-solving (assessed by validated instruments such as the Hermann' Assessment of Motivation Scale, (HAMS) have been largely overlooked. Moreover, the particular challenges of Iran's educational system, along with the necessity of developing protocols to integrate technology into officially approved curricula, make the case for context-specific research all the more compelling.

This study examines the impact of interactive computer simulations on architecture students' achievement motivation in the Building Structures course at Urmia Azad University (Iran), using the HAMS instrument. The research questions are:

1. Can computer simulations enhance students' achievement motivation when learning complex building concepts?
2. What advantages do simulations offer compared to traditional instruction?

This study makes three contributions: (1) the application of Hermans' framework as a comparative tool for classifying motivational patterns in Iran; (2) simultaneous measurement of psychological variables (motivation) and objective end-of-term outcomes; and (3) actionable strategies to address local implementation challenges.

The findings of this study are significant from two perspectives. At the micro level, the research provides a model for transforming theoretical classes into interactive learning environments in which instructors serve as facilitators of the concept-discovery process. At the macro level, it supplies local empirical data to inform the revision of curricula and the intelligent integration of digital technologies—especially in institutions where hands-on workshop resources are limited. Thus, the study deepens theoretical understanding of simulation efficacy and offers a strategic framework for evolving theoretical architecture education in Iran.

Research literature

Motivation is widely recognized as the principal driver of learning and a critical determinant of students' academic achievement. Research demonstrates that individual, environmental, and instructional factors interact complexly to shape motivational levels. For instance, Moammer Hoor et al. (2018) conducted a meta-analysis of 24 studies in Iran, identifying curriculum design, subject interest, goal orientation, self-efficacy, social support, and classroom emotional climate as primary determinants of academic motivation. Similarly, Harvey et al. (2023) implemented a motivational intervention in higher education, reporting a 32% increase in students' motivation and academic performance following active learning strategies and enhanced student autonomy.

The impact of simulation on student learning has been extensively evaluated. Xue et al. (2021) performed a systematic review in engineering education, concluding that simulation significantly enhances problem-solving skills. In geometry education, Zangeneh and Saedi (2017) compared

3D simulation to traditional instruction in an experimental study, finding superior learning outcomes with simulation. Xuefeng et al. (2020) reviewed 27 studies and confirmed that simulation bolsters critical thinking in science and engineering disciplines. Mehtari Arani et al. (2018) demonstrated through quantitative analysis that computer-based simulations improve psychological well-being and foster lifelong learning, while Czermainski de Oliveira et al. (2024) showed that simulated environments, by replicating cybernetic feedback mechanisms, can predict and optimize design outcomes.

Several researchers highlight the advantages of virtual and augmented reality in education. Jesionkowska et al. (2020) argue that VR/AR integration within STEM and art curricula enhances engagement and supports comprehensive active learning. Widiaty et al. (2022) conducted an experimental study in technical and vocational education, documenting improvements in comprehension, critical analysis, and learner confidence. Hsiang-Hui et al. (2022) similarly reported that simulation-based approaches yield higher motivation and engagement compared to conventional teaching methods.

Several studies have specifically examined the use of simulation in architectural education; In architectural pedagogy, Durisoto and Garrido (2016) and Kwon and Lawson (2015) emphasize simulation's pedagogical value in their monographs. Wang and Hu (2011) investigated simulation for spatial concept acquisition, Empirical studies by Apsan and Ergen (2008), Bowman and Kruijff (2003), and Wang and Hu (2023) examine simulation's influence on architecture students' motivation and participation. Sirror et al. (2021) underscore the necessity of structured instructional guidance for effective simulator use.

Recent evidence further supports simulation's role in architecture. Ning et al. (2024) reported that simulation elevates spatial scale understanding to levels comparable with real-world contexts. Ahmad et al. (2020) found that VR simulations increase interaction among students, instructors, and industry partners. Kwon and Lawson (2005) validated simulation's effectiveness in improving academic performance, and Kumar and Janardhan (2023) demonstrated that interactive digital tools enhance practical skills. Soliman et al. (2024) advocate for aligning architectural curricula with digital technologies to maximize learning outcomes.

Darwish et al. (2024) demonstrated that 3D simulation significantly improves the spatial reasoning of architecture students compared to traditional methods. In a systematic review of 19 articles, Taherysayah et al. (2024) reported that specifically designed virtual environments affect particular brain regions and support physiological and cognitive functions. Cardellicchio et al. (2024) explore virtual reality's capacity to convey intangible heritage qualities, and Ramadhan et al. (2024) show that immersive VR environments aid comprehension of architectural engineering principles. Memon et al. (2022) highlight the value of immediate feedback from digital tools in refining design solutions.

Despite the benefits, challenges remain. Vásquez-Carbonell (2022) reviews VR's limitations in engineering education, while Waters et al. (2021) emphasize the need for dedicated AR and simulation modules to enrich curricula. Aydede and Kesercioglu (2010) caution that simulation may detract from tactile understanding of materials. Al-Ansi et al. (2023) analyze 1,536 articles, noting substantial investment and customization requirements and a gap in translating digital advances into practice.

A systematic review of the existing literature reveals four key research gaps: (1) Inconsistent efficacy results: Prior studies report mixed outcomes regarding simulation's effectiveness in architecture. (2) Distinct educational paradigm: The interdisciplinary nature of architecture—blending artistic and technical expertise and delivered in art faculties at some universities and engineering faculties at others—yields an instructional model fundamentally different from that of other disciplines (Sedaghati & Hojat, 2020). (3) Neglected motivational mediators: Research has emphasized cognitive gains over motivational variables, such as those measured by the Hermans Achievement Motivation Scale. (4) Contextual limitations: There is a dearth of empirical research in developing countries, particularly Iran, where infrastructure deficits, faculty resistance, and misaligned curricula pose barriers. Guided by the Hermans model and employing a mixed-methods (experimental-survey) approach, this study investigates the impact of a computer simulator on architecture students' achievement motivation at Islamic Azad University, Urmia Branch. It also proposes a framework for localizing simulation technology in Iranian architectural education.

Materials and Methods

This study is applied in nature and, with respect to its objectives, can be categorized as a quasi-experimental design employing a control group for data collection. In this design, where participants are not randomly assigned, a two-group non-equivalent pretest–posttest design was used (Sarmad & Bazargan, 2022). This approach allows for direct comparison of intervention effects against standard instruction. In the current study, the experimental group comprised students who received an educational intervention utilizing computer-simulation technology, whereas the control group comprised students instructed through conventional lectures and activities. To evaluate the impact, academic motivation (the dependent variable) was measured pre- and post-intervention. The control group, which did not receive the simulation intervention, served as the basis for comparison.

The study was conducted from September 2022 to January 2023 at Urmia Azad University. The target population consisted of students enrolled in the Building Structures course. Using convenience sampling, n = 52 students were recruited. Cohen, Manion, and Morrison (2011) argue that in quasi-experimental designs, a minimum of 15 participants per subgroup is sufficient; accordingly, after three baseline sessions, a pretest measured academic motivation for all participants. Two groups were then formed—experimental (n = 26) and control (n = 26)—ensuring equivalent pretest means (see Table 1).

At this stage, the Hermans Achievement Motivation Inventory (29 multiple-choice items; 4-point Likert scale) was administered. Twelve items (Nos. 1, 4, 9, 10, 14–16, 20, 23, 27–29) were reverse-scored; higher total scores indicate greater motivation. The scale's reliability has been documented (α = .79–.87; Hermans, 1970; Abolghasemi, 2002; Akbari, 2007; Hooman & Askari, 2000); in this sample, Cronbach's α = .81, indicating acceptable internal consistency.

The experimental group then completed eleven weekly 90-minute computer-simulation sessions; the control group received eleven standard instructional sessions. No additional training was provided. Upon completion, the motivation inventory was re-administered. Experimental participants also responded to an open-ended question regarding simulation advantages and disadvantages, and field observations of engagement were recorded.

This study was conducted in accordance with the ethical principles of educational research. The following measures were systematically implemented:

- Before the study began, the research objectives, the intervention process, and the potential benefits and uses (such as using the data for scientific purposes) were communicated to participants both verbally and in writing, and participation was voluntary.
- The students' identifying information was replaced with anonymized codes and the data were stored in encrypted form. Only the principal investigator had access to the raw data.
- Given the educational nature of the intervention, no significant physical or psychological risks were anticipated. However, to prevent anxiety arising from the assessments, it was emphasized

that the pre-test and post-test scores would be used solely for research purposes and would not affect the students' grade point averages.

This study had several limitations. The primary ones included:mLimited sample size and use of a convenience sample; Students' concerns about how their questionnaire responses might influence their evaluation, leading some to complete the questionnaire reluctantly; Limited domestic and international literature on the topic; The absence of a workshop for implementing the training; Technical limitations (such as poor internet connectivity and insufficient hardware); Logistical challenges in preparing the students and the classroom for the sessions; The absenteeism of some students in multiple sessions; A focus on the content of a single course; A limited timeframe for the training; Difficulties in developing the educational software.

The research process is presented in Fig. 1.

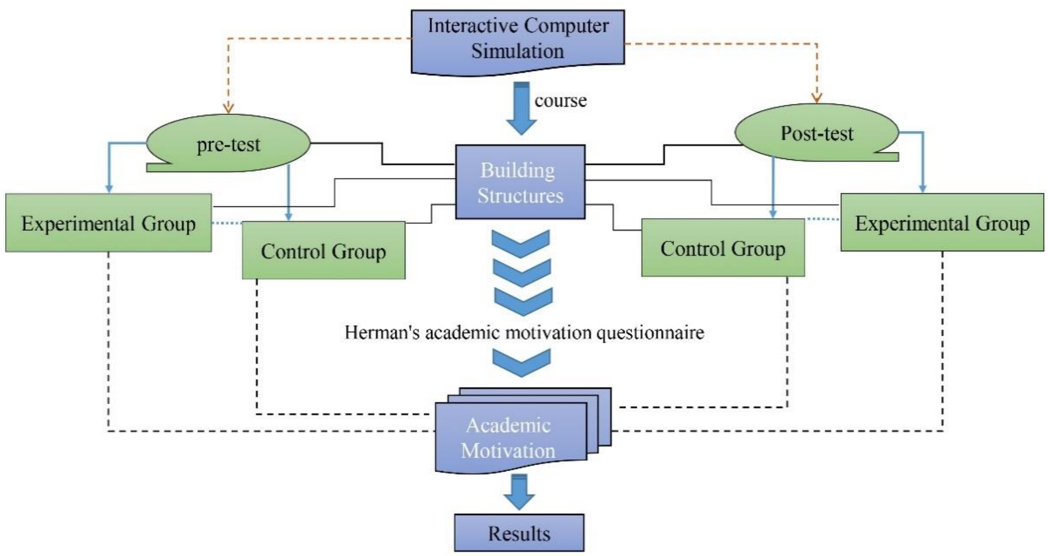

Fig. 1. Theoretical framework

Results

According to Table 1, the experimental group mean was 17.05 (SD = 1.94), and the control group mean was 17.08 (SD = 2.11). An independent-samples t-test indicated T=-0.15, $p > 0.05$, confirming no significant difference in baseline achievement motivation between groups. After the instructional interventions, participants completed a post-test (see Table 4).

Table 2. The average scores of the two test and control groups after 3 class sessions in the usual way

Standard deviation	Mean	Number	Name	Group

1.94	17.05	26	A	Experimental
2.11	17.08	26	B	Control

After collecting the questionnaires and categorizing the data, the analysis was conducted using SPSS software. This analysis was performed at two levels: descriptive statistics and inferential statistics. In the descriptive statistics section, indicators such as the mean and standard deviation of scores were examined. In the inferential statistics section, after verifying the necessary assumptions, an analysis of covariance (ANCOVA) test was used for data analysis.

Table 2 presents the descriptive statistics related to the mean and standard deviation of scores for the experimental and control groups in both the pre-test and post-test phases. As observed, in the pre-test phase, there is no significant difference between the mean achievement motivation scores of students in the two groups. However, in the post-test phase, the mean achievement motivation score in the experimental group increased compared to the control group. Nevertheless, to determine the statistical significance of this increase, the results of the inferential analysis must be considered.

Table 3. Average and deviations of pre-test and Post-test

Control group	Experimental group		
82.94	82.68	Mean	Pretest
9.98	10.12	(SD) Standard deviation	
83.86	93.08	Mean	posttest
10.04	8.16	(SD) Standard deviation	

Given the interfering variable is measurable and often considered quantitatively, we cannot ignore its effect when examining and measuring the dependent variable. Therefore, by maintaining the effects of the interfering variable constant, we identify the equality of the mean value of the dependent variable at different levels of the factor variable. As a result, a one-way analysis of covariance (ANCOVA) was used to assess effectiveness.

First, the assumptions for the ANCOVA analysis were tested. The results of the Shapiro-Wilkes test indicated that the significance level was higher than 0.05. (F=0.95), and the variables are normally distributed, thus confirming the homogeneity assumption of the variable distribution in the data. Additionally, in order to test the homogeneity of the variables, Levene's test was used, yielding an F value of 0.86. Therefore, the significance level exceeded 0.05, and the assumption of homogeneity of variances is confirmed.

The examination into the homogeneity of the regression slope grades, an F value of 1.38 was obtained, indicating that the mutual vectors were not significant and there was no significant difference in the regression slope between the two groups (at a 0.05 level of error). Based on the results of the M Box test (0.76), the null hypothesis is confirmed, suggesting that the assumption of homogeneity of covariance of dependent variables within the groups holds.

After ensuring the homogeneity of the variables, a covariance test was performed, and Table 3 shows the test results for comparing motivation progress in the post-test phase. The table results and an F value of 97.131, along with the significance level, and the higher mean scores of the experimental group in the post-test phase, indicate that the learning of students trained using simulation methods is different from those trained using conventional methods.

Table 4. The result of analysis of covariance test for two experimental and control groups

Significance level	Eta coefficient(η^2)	F value	Mean of squares(MS)	Degrees of freedom (df)	Sum of squares(SS)	
0.0001	0.747	147.600	2483.228	1	2483.228	Pretest
0.0001	0.66	97.131	1634.125	1	1634.125	Group
			16.824	50	841.217	Error

At the end of the term, following completion of their respective instructional activities, both the experimental and control groups undertook the post-test. The results indicated that the experimental group achieved a mean score of 17.86, whereas the control group's mean was 17.12. A univariate ANCOVA—controlling for pretest scores—was conducted to compare the two groups. The analysis yielded a statistically significant effect (see Table 4), demonstrating that the learning gains of students in the simulator-based instructional group were significantly greater than those of the control group.

Table 5. Covariance analysis of the final exam

D	P	F	Standard deviation	Mean	Number	Name	Group
0.66	0.0001	20.16	1.98	17.86	26	A	Experimental
			2.02	17.12	26	B	Control

Based on field observations during the term, teaching experience with this technology, review of the literature, and analysis of student responses to the end-of-term questionnaire, the following potential advantages (and possible limitations) of this technology can be identified:

Unlimited experimentation and iterative refinement: Simulation enables students to test ideas in a safe, cost-free environment, identify and correct errors, and optimize solutions in real time. Exploring varied structural scenarios also provides a comprehensive understanding of construction processes and performance.

Access to diverse exemplars: Computer-based simulation tools grant exposure to architectural and building-system models that might be impractical to observe physically.

Experiential learning of complex concepts: By presenting processes in three-dimensional, interactive formats, simulators facilitate comprehension of abstract topics (e.g., interior design, material behavior) that are challenging in traditional lectures. **They also eliminate time and space constraints by replacing physical models with virtual practice.**

Bridging theory and practice: Simulations connect classroom theory with real-world applications, increasing motivation and fostering proficiency in digital modeling and structural analysis before professional practice.

Enhanced engagement and motivation: Interactive, gamified elements stimulate curiosity and participation, leading to deeper, sustained engagement with course content.

Improved problem-solving skills: Immersive 3D environments lower cognitive barriers to experimentation, accelerating solution iteration and enhancing creative strategies (cf. Ozenen, 2022; Huang, 2024).

Reduced anxiety: Self-paced simulation experiences build confidence and reduce stress by allowing learners to progress without performance pressure.

Facilitated self-directed learning: Ready access to varied examples and up-to-date resources supports autonomous study (cf. Widiaty et al., 2022; Kee, 2024).

Lowered cognitive load: Focused, multisensory simulations concentrate attention on essential tasks, reducing extraneous cognitive demands.

Multisensory immersion: Visual, auditory, and haptic feedback enrich understanding of spatial and structural details, deepening conceptual grasp.

Cultivation of creativity: Playful exploration in virtual environments encourages risk-taking and broadens design vocabulary.

Resource optimization: Simulations reduce reliance on studios and physical materials, aligning pedagogy with modern digital and industry standards.

Cost reduction and risk mitigation: Virtual experiments replace costly, hazardous physical models, enabling safe technical practice.

Unlimited practice and immediate feedback: Real-time performance evaluation and error detection accelerate mastery.

Real-world condition modeling: Advanced simulators replicate factors (e.g., seismic loads, wind stresses) to assess building performance under realistic conditions.

Objective assessment: Automated evaluation minimizes subjective grading, promotes equity, and streamlines instructor feedback.

Despite these advantages, implementing computer-based simulators in architectural education presents several challenges:

Infrastructure and cost constraints: High-fidelity simulation demands advanced hardware/software and reliable internet, posing financial and logistical barriers (cf. Al Ansi et al., 2023).

Erosion of manual skills: Excessive reliance on digital tools may diminish hands-on drafting and tactile understanding (cf. Omar et al., 2016).

Potential stifling of creativity: Preconfigured templates risk guiding learners into narrow design paths, limiting inventive exploration.

Incomplete concept transmission: Simulators may fail to convey nuanced, abstract pedagogical content, necessitating complementary traditional methods (cf. Anindita et al., 2022).

Technological immaturity and glitches: Software–hardware mismatches and model inaccuracies can lead to misconceptions (cf. Puggioni et al., 2021; El Barhoumi, 2022; Matusiak, 2008).

Resistance to adoption: Faculty and students may resist curricular changes and new technologies.

Need for instructor training: Effective deployment requires professional development to align software use with learning objectives.

Maintenance and licensing costs: Frequent updates and licensing fees can impose ongoing financial burdens.

Complexity and digital literacy: Sophisticated interfaces may overwhelm users lacking strong computing skills.

Diminished instructor authority: Overreliance on automation may undermine traditional pedagogy and assessment methods.

Over-engagement and isolation: Highly immersive simulations can distract from core conceptual learning and reduce collaborative critique.

Increased cognitive load: Mastery of software mechanics may divert focus from deep conceptual understanding.

Reduced social interaction: Individual virtual experiences can erode peer and instructor engagement essential in architecture.

Data interpretation challenges: Complex simulation outputs require precise instructor guidance to avoid misapplication (see Fig. 2).

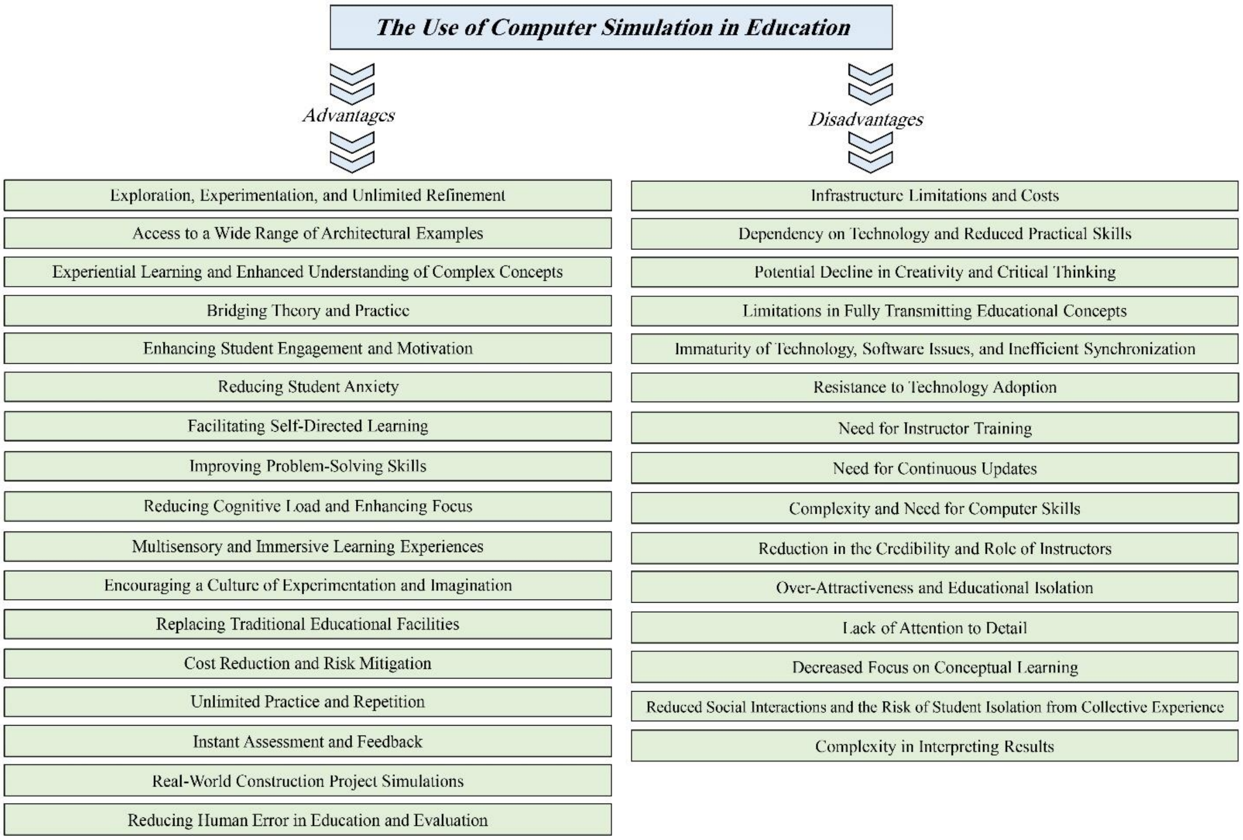

Fig. 2. Advantages and Disadvantages of Using Simulation in Education

Discussion

This study examined the impact of computer-based interactive simulation (CBIS) on architecture students' motivation to progress in the Building Structures course, providing clear evidence of its effectiveness. The experimental group's mean progress-motivation score increased by 10.4 points (from 82.68 to 93.08), whereas the control group's score showed only a negligible change (0.92 points). An ANCOVA confirmed a significant difference between the two groups, with a large effect size ($\eta^2 = 0.66$) suggesting that 66% of the variance in scores is attributable to the intervention. Furthermore, an independent t-test on pre-intervention knowledge scores revealed no significant difference between the groups (experimental mean 17.05 ± 1.94 vs. control 17.08 ± 2.11; $p > 0.05$). This initial equivalence reduces the likelihood that confounding factors—such as differences in baseline knowledge or prior educational experience—affected the results, thereby strengthening the study's internal validity. The reduction in the experimental group's standard deviation from 10.12 to 8.16 indicates that post-intervention scores were more homogeneous, with most students improving in a consistent manner. This outcome suggests that the instructional approach was effective across a wide range of learners. In contrast, the control group's standard deviation remained roughly constant (around 10), indicating that score dispersion in this group was unchanged.

The experimental group's improved academic performance on the final exam (mean 17.86 vs. 17.12 in the control group; $p < 0.0001$) confirms that CBIS enhances not only motivation but also mastery of complex technical concepts. These findings can be interpreted through four key theoretical frameworks:

1. **Self-Determination Theory (Deci & Ryan, 2000):**
    - **Autonomy:** Students manipulated variables.
    - **Competence:** Immediate, multi-sensory feedback reinforced skill mastery.
    - **Relatedness:** Collaborative virtual projects fostered peer engagement.

    These mechanisms align with Widiaty et al. (2022), who identify self-directed learning as a key motivator in digital learning environments.
2. **Kolb's Experiential Learning Cycle (1984):** The simulation facilitates learning through four stages: Concrete experience:
    - **Concrete Experience:** Virtual testing without risk.
    - **Reflective Observation:** Visual collapse simulations revealed causal links.
    - **Abstract Conceptualization:** Theoretical principles emerged from practice.
    - **Active Experimentation:** Rapid iteration reinforced learning control.
3. **Bandura's Self-Efficacy Theory (1997):** The multi-sensory feedback (visual, numerical, auditory) in CBIS enables mastery experiences and social modeling. For example, students who achieved small successes in earthquake simulations reported increased confidence in their ability to solve complex problems.
4. **Atkinson's Achievement Motivation Theory** (Atkinson, 1964)**:** Motivation is conceptualized as a combination of expectancy of success and the value placed on goals. The simulation, through mechanisms such as multi-sensory immediate feedback and realistic scenario simulation (e.g., designing structures under earthquake conditions),

enhances both the expectancy of success and the perceived goal value. This mechanism is consistent with the findings of Apsan and Ergen (2009), who regard intrinsic motivation as the primary driver of deep learning in architecture.

Despite clear benefits, sustainable CBIS implementation requires addressing:

Constraints on creativity: Preset templates may limit design flexibility. This observation aligns with Omar et al. (2016), who warn that the overuse of digital tools may undermine critical thinking and manual skills.

Infrastructure barriers: High hardware/software costs and uneven internet access (Al-Ansi et al., 2023).

Cognitive overload: Some students experienced cognitive overload due to the complexity of the software. Furthermore, the intrinsic appeal of simulation environments may divert focus from deep learning to competing for virtual points.

Faculty training needs: Instructors lacking technical skills might resort to superficial uses of CBIS, undermining its potential. This issue is consistent with the findings of Anindita et al. (2022), who identify inadequate faculty training as a main factor in the failure of digital education initiatives.

Recommendations

To maximize the benefits of CBIS, the following recommendations are proposed:

Curriculum redesign: Integrate real-world scenarios (such as earthquake or fire simulations) into specialized courses. Develop hybrid modules that combine digital simulations with practical workshops (such as constructing physical models).

Investment in infrastructure: Utilize cloud platforms to reduce hardware costs. Establish workshops and classrooms equipped with digital technology.

Faculty development: Conduct training workshops for mastering the software and designing interactive scenarios. Create a network of leading faculty to share experiences.

Managing psychological challenges: Design simpler user interfaces to reduce cognitive load. Incorporate debriefing sessions with instructors to interpret simulation results.

Designing intelligent simulators: Use artificial intelligence to personalize content according to students' learning pace. Develop multiplayer interactive environments to reinforce social interaction and prevent isolation.

This study indicates that computer-based interactive simulation, by redefining students' relationship with the learning process, can transform the paradigm of architectural education. On the one hand, this technology—by enhancing intrinsic motivation, perceived competence, and self-directed learning—transforms students into architect–researchers prepared to face the complex challenges of the construction industry; on the other hand, challenges such as constraints on creativity, infrastructure costs, and the need for instructor retraining present serious barriers to its widespread implementation. As Matusiak (2008) emphasizes, architecture is born of earth, not silicon, and thus the success of CBIS depends on maintaining a delicate balance between digital innovation and professional authenticity. Therefore, it is recommended that this technology be regarded not as a replacement but as a complement to traditional methods, enabling both the harnessing of its transformative potential and the avoidance of risks associated with reduced tactile interaction with physical materials. Such an approach would represent a step toward transforming traditional architecture classrooms into interactive digital workshops, in which students not only learn concepts but also cultivate a passion for lifelong learning.

Future studies could focus on the mediating role of variables such as self-efficacy, critical thinking, and creativity. Furthermore, examining the long-term impact of CBIS on design standardization and the development of AI-based simulators is a promising direction for future research. Ultimately, realizing this vision will require interdisciplinary collaboration among architects, educational psychologists, and technology engineers to steer architectural education in a direction that leverages technological advancements while preserving its artistic authenticity.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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