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Research Paper

Reimagining Architectural Education through Interactive Simulation: A Quasi-Experimental Investigation of Academic Motivation in Building Structures Education

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Abstract
Academic motivation is a critical determinant of students' engagement, learning effectiveness, and academic achievement. In architectural education, technically oriented courses such as Building Structures are often perceived as more challenging and less engaging than design studio courses, which may negatively affect students' motivation and learning experiences. Consequently, identifying innovative instructional approaches that enhance students' academic motivation has become an important objective in higher education. This study investigates the effectiveness of interactive computer simulation-based instruction in enhancing the academic motivation of undergraduate architecture students enrolled in a Building Structures course. A quasi-experimental pre-test–post-test design with a control group was employed. The study involved 50 undergraduate architecture students at Urmia Islamic Azad University, who were assigned to either an experimental group (n = 25) or a control group (n = 25). The experimental group received instruction through an interactive computer simulation environment, whereas the control group was taught using conventional lecture-based methods. Academic motivation was assessed using the Hermans Achievement Motivation Questionnaire (AMT). Data were analyzed using descriptive statistics and analysis of covariance (ANCOVA). The findings revealed a statistically significant increase in academic motivation among students who participated in simulation-based instruction compared with those who received traditional instruction. In addition, students in the experimental group achieved significantly higher scores on the final examination than their counterparts in the control group. These findings indicate that interactive computer simulation can serve as an effective pedagogical strategy for enhancing both academic motivation and learning outcomes in Building Structures education. The study contributes to the growing body of research on technology-enhanced learning in architectural education by providing empirical evidence from a technical course context that has received comparatively limited attention in previous studies.

Keywords: *Academic motivation, Architectural education, Building structures, Interactive computer simulation, Technology-enhanced learning.*

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INTRODUCTION

Academic motivation is widely recognized as one of the most influential determinants of learning, academic achievement, persistence, and educational success. As a fundamental psychological construct, motivation provides the cognitive and emotional energy that drives learners toward educational goals and shapes their willingness to invest effort in academic activities. Extensive research has demonstrated that students with higher levels of academic motivation exhibit greater engagement, persistence, self-regulation, creativity, and overall academic performance than their less motivated peers (Saif, 2022a; Skinner et al., 2008). Consequently, enhancing students' motivation has become a central objective of contemporary higher education, particularly in disciplines that require sustained intellectual engagement and complex problem-solving abilities.

Architecture education presents unique pedagogical challenges because it integrates artistic creativity, technical knowledge, engineering principles, and design thinking within a single educational framework (Sedaghati & Hojat, 2020). Students enrolled in architecture programs are expected to develop competencies that range from conceptual design and spatial visualization to structural analysis and building technology. While architecture students often demonstrate strong enthusiasm for design studios and creative activities, their motivation may decline in technically oriented courses that involve abstract engineering concepts and complex building systems. Among these courses, *Building Structures* occupies a central position within the architecture curriculum because it provides the technical foundation necessary for understanding structural behavior, construction technologies, environmental performance, and sustainable building practices. Despite its importance, students frequently perceive this course as difficult, theoretical, and disconnected from real-world design experiences, which can negatively affect their motivation and learning outcomes.

Recent advances in educational technology have created unprecedented opportunities to address such challenges through innovative teaching and learning approaches. Among these developments, computer simulation has emerged as a particularly promising instructional tool capable of transforming traditional teacher-centered environments into interactive and learner-centered educational experiences. Simulation-based learning enables students to visualize complex phenomena, manipulate variables, test alternative scenarios, and receive immediate feedback regarding the consequences of their decisions. Unlike conventional lecture-based instruction, simulation environments promote active participation, experiential learning, and knowledge construction through exploration and discovery. These characteristics align closely with contemporary constructivist learning theories, which emphasize the active role of learners in the development of meaningful understanding.

The educational value of simulation technologies has been extensively documented across a wide range of disciplines, including engineering, medicine, science, and vocational education. Previous studies have reported that simulation-based instruction can significantly improve conceptual understanding, problem-solving skills, critical thinking, engagement, academic achievement, and learner motivation (Al-Ansi et al., 2023). Meta-analytic evidence further suggests that simulation environments facilitate deeper learning by allowing students to connect theoretical knowledge with practical applications in authentic learning contexts. Consequently, simulation-based learning has become an increasingly important component of technology-enhanced education.

Within architecture education, digital technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and computer simulation have attracted considerable attention during the last decade. Researchers have demonstrated the effectiveness of these technologies in improving spatial cognition, design visualization, environmental analysis, scale perception, and immersive learning experiences (Darwish et al., 2023; Hou et al., 2023; Kharvari & Kaiser, 2022). Simulation technologies allow architecture students to interact with virtual representations of architectural systems that may otherwise be difficult, expensive, time-consuming, or impossible to observe directly. Through these environments, learners can explore the dynamic behavior of building components, evaluate design alternatives, and gain a deeper understanding of the relationships among structural, environmental, and functional building systems.

Despite the growing adoption of simulation technologies in architectural education, important gaps remain in the existing body of knowledge. A review of the literature reveals that most previous studies have focused primarily on architectural design studios, virtual reality applications, spatial cognition, visualization processes, and immersive design environments. Comparatively little attention has been devoted to technical and engineering-oriented courses that constitute a substantial portion of architecture curricula. Moreover, although academic motivation is widely acknowledged as a critical factor influencing learning effectiveness and educational success, relatively few studies have examined the impact of simulation-based instruction on motivational outcomes among architecture students. Existing research has generally emphasized cognitive outcomes such as spatial ability, design performance, and conceptual understanding, while motivational dimensions have received considerably less empirical attention.

This limitation is particularly important because motivation serves as a prerequisite for sustained learning and professional development. Students who are more motivated are more likely to engage actively with course content, persist when confronted with challenges, and achieve higher levels of academic success. Therefore, understanding how innovative instructional technologies influence academic motivation represents an important research priority for architecture education. Furthermore, the specific context of *Building Structures* courses remains underexplored despite its educational significance and the challenges commonly experienced by students in mastering technical architectural concepts.

Accordingly, the present study investigates the impact of interactive computer simulation-based instruction on the academic motivation of undergraduate architecture students enrolled in a Building Structures course. By focusing on a technical architecture course rather than a design studio environment, this research extends the current literature on simulation-based learning into a relatively underexamined educational context. In addition, it contributes to the growing body of research on technology-enhanced learning by examining both motivational and academic outcomes associated with simulation-based instruction.

More specifically, this study addresses the following two research questions:

RQ1: Does interactive computer simulation-based instruction significantly improve the academic motivation of architecture students enrolled in a *Building Structures* course compared with conventional teaching methods?

RQ2: Does simulation-based instruction significantly improve students' academic achievement in a *Building Structures* course compared with conventional instruction?

Based on these questions, the following hypotheses were formulated:

H1: Students receiving simulation-based instruction will demonstrate significantly higher levels of academic motivation than students receiving conventional instruction.

H2: Students receiving simulation-based instruction will achieve significantly higher academic performance than students receiving conventional instruction.

The study contributes to the literature in three important ways. First, it extends simulation-based learning research to the context of *Building Structures* education, an area that has received limited empirical attention despite its importance within architecture curricula. Second, it provides evidence regarding the influence of interactive computer simulation on architecture students' academic motivation, thereby addressing a notable gap in previous research. Third, it offers practical implications for curriculum development and instructional innovation by demonstrating how simulation technologies can be integrated into technical architecture courses to enhance both student motivation and learning outcomes.

RESEARCH LITERATURE

Academic Motivation in Higher Education

Academic motivation has long been recognized as one of the most influential determinants of students' learning behaviors, engagement, persistence, creativity, and academic achievement. Educational psychologists define motivation as a set of internal and external processes that initiate, direct, and sustain learning-related behaviors (Saif, 2022b). Contemporary theories of motivation emphasize that motivated learners are more likely to engage actively in learning activities, invest greater effort in academic tasks, and achieve higher levels of educational success (Urhahne & Wijnia, 2023).

The theoretical foundations of academic motivation can be traced to achievement motivation theory, self-determination theory, expectancy–value theory, and social-cognitive perspectives. According to Skinner et al. (2008), motivation directly influences students' behavioral and emotional engagement in academic activities. Similarly, Haru (2023) argues that achievement motivation serves as a key predictor of academic performance and persistence in higher education. From a social-cognitive perspective, self-efficacy and perceived competence strongly influence students' willingness to engage in challenging learning tasks (Sadeghi et al., 2022).

Several studies have investigated the determinants of academic motivation in university settings. Through a meta-analysis of Iranian studies, Moammer Hoor (2020) identified curriculum quality, the learning environment, teaching methods, self-efficacy, family support, and academic goals as major predictors of student motivation. Similar findings were reported by Ebrahimi et al. and Sadeghi et al., who demonstrated significant relationships between academic motivation, educational engagement, and learning outcomes in higher education contexts.

Recent international evidence further highlights the role of instructional strategies in enhancing academic motivation. Fuertes et al. (2023) found that student engagement significantly mediates the relationship between motivation and academic achievement. Active teaching methodologies have been shown to enhance both students' intrinsic motivation and learning outcomes in higher education. For example, active learning strategies implemented in architectural engineering courses created dynamic learning environments in which students were more engaged, motivated, and better able to comprehend theoretical concepts, leading to improved learning quality and greater preparedness for professional challenges (Sukkar et al., 2023). Similarly, a systematic review of motivational teaching techniques concluded that the adoption of diverse, student-centered active learning approaches—such as project-based learning, problem-based learning, collaborative learning, and flipped classrooms—enhances both motivation and academic achievement, particularly when students work on authentic problems and receive continuous feedback (Costa & Reis, 2025). Likewise, a large meta-analysis of problem-based, project-based, and case-based learning demonstrated that student-centered, problem-driven instructional approaches produce small to moderate positive effects on students' motivational beliefs, task values, and attitudes compared with traditional lecture-based teaching (Wijnia et al., 2024).

A growing body of research also suggests that intrinsic motivation is more strongly associated with deep learning and long-term academic success than extrinsic forms of motivation. A comprehensive review of 58 studies reported that intrinsic motivation, grounded in autonomy, competence, and relatedness, promotes deep learning, creativity, and sustained engagement. In contrast, extrinsic motivation primarily supports short-term performance and goal attainment and may even undermine intrinsic interest when overemphasized (Bandara & Hettiwaththage, 2025). Consistent with these findings, Kamberi (2025) reported that the intrinsic motivation dimension of "motivation to know" was positively and directly associated with academic achievement, while deep learning strategies mediated the effects of certain intrinsic motivational orientations on performance. Similarly, research on learning approaches has shown that strong intrinsic motivation encourages deep learning strategies, which in turn predict higher academic achievement, whereas surface learning approaches are associated with lower levels of academic performance (Everaert et al., 2017). Furthermore, Sadeghi et al. (2022) demonstrated that academic motivation significantly predicts creativity among architecture students, underscoring its critical role in architectural education.

Active Learning, Simulation-Based Education, and Learning Effectiveness

Traditional teacher-centered approaches have increasingly been challenged by active learning paradigms that emphasize student participation, interaction, and experiential learning. Active learning approaches encourage students to construct knowledge through exploration, reflection, and engagement rather than through the passive reception of information (Aydede & Kesercioğlu, 2010).

Among these approaches, simulation-based learning has emerged as one of the most effective pedagogical strategies for promoting active engagement. Educational simulations provide learners with opportunities to interact with realistic representations of complex systems and phenomena within controlled environments, enabling them to practice skills, test decisions, and receive immediate feedback without exposure to real-world risks (Almasri, 2022).

A growing body of evidence from systematic reviews and meta-analyses demonstrates that simulation-based instruction significantly enhances learning outcomes across a wide range of educational disciplines. In nursing and healthcare education, for example, virtual and high-fidelity simulations have been shown to produce substantial improvements in knowledge acquisition, clinical reasoning, and professional performance compared with traditional instructional approaches (Lei et al., 2022; Sim et al., 2022). Similarly, meta-analytic research on psychiatric simulation training has reported large positive effects on skill development and favorable impacts on learners' attitudes relative to conventional educational methods (Piot et al., 2021).

Comparable findings have been reported in other educational fields. Research on experiential and simulation-based environments in finance education indicates that such approaches provide authentic, hands-on learning experiences, foster deep learning strategies, and enhance student engagement and satisfaction (Bakoush, 2022). Likewise, studies conducted in science and medical education have documented high levels of learner engagement, motivation, and satisfaction, accompanied by significant improvements in conceptual understanding and procedural knowledge (Almasri, 2022; Wu et al., 2022).

One of the most comprehensive investigations in this area was conducted by Chernikova et al. (2020), whose meta-analysis of 145 empirical studies revealed a large overall positive effect of simulation-based instruction on the development of complex skills (g = 0.85). Their findings demonstrated robust benefits across diverse disciplines, including medicine, nursing, teacher education, management, engineering, and economics, suggesting that simulation-based learning frequently outperforms traditional instructional methods. Similarly, Burch et al. (2019) synthesized evidence from 89 empirical studies spanning more than four decades and found that experiential learning approaches, many of which incorporated simulation-like and hands-on learning environments, generated significantly better educational outcomes than conventional teaching methods. Specifically, students exposed to experiential learning achieved outcomes nearly half a standard deviation higher (d = 0.43) than those receiving traditional instruction.

Beyond general academic performance, simulation-based instruction has also been associated with the development of higher-order cognitive skills. Simulation-based learning not only enhances knowledge acquisition but also promotes the cognitive processes required for complex decision-making and professional practice.

The effectiveness of simulation technologies has been documented across diverse educational contexts. Miller et al. (2019) found that simulation-based training significantly improves professional competence in medical education. Similarly, Mehtari Arani et al. (2019) reported improvements in students' subjective well-being and lifelong learning competencies following participation in computer-based educational simulations. In the context of secondary education, Zangeneh & Saedi (2017) demonstrated that three-dimensional simulation environments significantly enhance learning outcomes and knowledge retention.

In addition to cognitive and academic benefits, simulation technologies appear to exert a positive influence on psychological and motivational factors. Annafi et al. (2019) concluded that augmented reality applications improve students' understanding, thinking skills, and motivation. Likewise, Jesionkowska et al. (2020) found that augmented reality supports active learning processes and promotes student participation in STEAM education.

More recent studies have continued to reinforce these findings. Amin et al. (2022) reported that virtual reality applications improve critical thinking, self-confidence, and overall learning effectiveness. Waters et al. (2021) demonstrated that augmented reality significantly enhances students' three-dimensional visualization skills in engineering education. Huang and Musah (2024) further found that augmented reality positively influences creativity, student behavior, and pedagogical effectiveness. Likewise, Puggioni et al. (2021) showed that virtual reality platforms contribute to improved learning experiences and higher levels of academic engagement.

Within the context of architectural education, where students are required to understand complex relationships among structural systems, building technologies, environmental performance, and design decisions, simulation-based instruction offers unique pedagogical advantages. By enabling learners to visualize dynamic building processes, explore alternative design scenarios, and interact with realistic representations of architectural systems, simulation technologies have the potential to transform learning experiences in technical architecture courses. Such technologies facilitate the integration of theoretical knowledge with practical application, thereby supporting deeper conceptual understanding and more meaningful learning experiences.

Virtual Reality, Augmented Reality, and Simulation Technologies in Architectural Education

Technological advancements have significantly transformed architectural education over the past two decades, reshaping both pedagogical approaches and learning environments. The integration of digital technologies has expanded opportunities for visualization, interaction, experimentation, and collaborative learning, enabling students to engage with architectural concepts in more dynamic and immersive ways. Omar et al. (2020) demonstrated that three-dimensional simulation modeling enhances students' understanding of architectural design concepts by facilitating the visualization of complex spatial and structural relationships. Similarly, Soliman et al. (2019) argued that digital technologies are fundamentally reshaping architectural pedagogy and professional practice, bridging the gap between academic instruction and industry demands. In the same vein, Kumar and Janardhan (2023) emphasized the transformative role of emerging technologies in shaping the future of architectural education, highlighting their potential to improve learning effectiveness and professional preparedness.

The educational value of simulation technologies has also been examined from cognitive and perceptual perspectives. Hou et al. (2024) demonstrated that virtual reality (VR) environments significantly improve students' perception of architectural scale and spatial experience, enabling learners to develop a more realistic understanding of built environments. Likewise, Darwish et al. (2023) found that extended reality (XR) technologies substantially enhance spatial abilities among architecture students, thereby supporting design thinking and architectural problem-solving. Earlier research by Matusiak and Sudbø (2008) further illustrated how computer simulations contribute to understanding spatial perception and the environmental qualities of architectural spaces, providing valuable insights into how individuals experience and interpret the built environment.

Recent developments in educational technology have further expanded the range of digital tools available for architectural education. Ahmad et al. (2020) demonstrated the effectiveness of online and virtual teaching methodologies in design education during the COVID-19 pandemic, highlighting the adaptability of digital learning environments in maintaining educational continuity. Similarly, Kee et al. (2024) emphasized the growing role of generative artificial intelligence in architectural education, arguing that AI-based tools can enhance digital literacy, creativity, and holistic professional competencies among architecture students. Furthermore, de Oliveira et al. (2024) highlighted the importance of systems thinking and feedback mechanisms in design education, emphasizing how technology-supported learning environments can facilitate iterative learning processes. El Barhoumi et al. (2022) also investigated various augmented reality (AR) techniques for three-dimensional model visualization and reported their effectiveness in improving students' understanding of spatial and geometric relationships.

New Technologies in Building and Construction Education

Although a substantial proportion of simulation-related research in architecture has focused on design studios, visualization, and spatial cognition, increasing attention has recently been directed toward technical and construction-oriented courses. Such courses often involve abstract concepts and complex systems that can be difficult for students to comprehend through conventional teaching methods alone. Simulation technologies offer opportunities to bridge this gap by providing interactive and visually rich learning experiences.

Memon et al. (2022) demonstrated that simulated learning environments significantly improve learning experiences in architecture, engineering, and construction (AEC) programs by fostering active participation and experiential learning. Similarly, Ramadhan et al. (2024) reported positive student experiences with virtual reality applications in Building Information Modeling (BIM) courses, indicating that immersive technologies can facilitate understanding of complex construction processes and digital workflows. Anindita et al. (2022) further found that building-performance simulation tools effectively support architectural design learning and technical decision-making processes by enabling students to evaluate alternative design solutions and assess building performance outcomes.

Evidence from recent review studies further supports the educational effectiveness of immersive technologies in construction and building-related education. Man et al. (2024), through a systematic review and meta-analysis, concluded that virtual reality applications significantly improve safety training outcomes in construction education by increasing learner engagement and enhancing knowledge retention. Likewise, Cardellicchio et al. (2024) demonstrated the effectiveness of virtual reality for communicating complex construction processes and heritage-building documentation, suggesting that immersive environments can facilitate the understanding of intricate technical information. Moreover, Taherysayah et al. (2024), in a systematic review of studies combining virtual reality and neurophysiological measures, found substantial evidence that immersive environments influence cognitive, emotional, and behavioral processes associated with architectural learning, thereby supporting more effective educational experiences.

At a broader level, Al-Ansi et al. (2023) analyzed recent developments in augmented reality and virtual reality technologies and concluded that these technologies are becoming increasingly influential across educational settings worldwide. Their review highlighted numerous educational benefits, including enhanced engagement, visualization, interactivity, and learning effectiveness. Nevertheless, they also identified several challenges related to infrastructure requirements, implementation costs, technological accessibility, and pedagogical integration. Similarly, Vásquez-Carbonell (2022) pointed out the lack of standardized methodologies for evaluating virtual reality interventions in educational contexts, emphasizing the need for additional empirical studies conducted within specific disciplinary settings.

Research Gap and Contribution of the Present Study

The existing literature provides substantial evidence regarding the educational benefits of active learning, simulation-based instruction, virtual reality, augmented reality, and other technology-enhanced learning approaches. Previous studies have consistently reported positive effects on academic achievement, conceptual understanding, spatial cognition, critical thinking, engagement, creativity, professional competencies, and overall learning effectiveness across a variety of educational disciplines. Furthermore, research on academic motivation has highlighted the critical role of instructional strategies and learning environments in fostering students’ engagement, persistence, and academic success.

Despite these advances, several important gaps remain in the literature. First, most studies in architectural education have concentrated on design studios, visualization activities, spatial cognition, and design-oriented learning environments, whereas relatively little attention has been devoted to the application of simulation-based instruction in technical architecture courses such as Building Structures. Second, although the educational effectiveness of simulation technologies has been widely documented, existing research has focused predominantly on cognitive and performance-related outcomes, with considerably less emphasis on motivational outcomes. In particular, empirical evidence concerning the influence of simulation-based instruction on architecture students' academic motivation remains scarce.

Third, much of the existing evidence originates from engineering, medical, and science education contexts, limiting our understanding of how simulation-based learning functions within architecture programs. Fourth, empirical studies conducted in developing-country higher education settings remain relatively limited, thereby restricting the generalizability of current findings across diverse educational and cultural contexts. Finally, while virtual reality and augmented reality technologies have been increasingly incorporated into architectural education, relatively few studies have examined their effectiveness in supporting the teaching and learning of technical building-system concepts that are often perceived by students as abstract, complex, and difficult.

Addressing these gaps is particularly important because academic motivation plays a central role in sustaining student engagement, persistence, and achievement in technically demanding courses. Building Structures courses constitute a fundamental component of architectural education, yet they frequently present motivational challenges due to the abstract and engineering-oriented nature of their content. Consequently, identifying instructional approaches that can simultaneously improve learning outcomes and strengthen students' motivation represents an important educational priority.

Accordingly, the present study investigates the impact of interactive computer simulation-based instruction on the academic motivation and academic achievement of architecture students enrolled in a Building Structures course. By focusing on a technical component of the architecture curriculum, emphasizing motivational outcomes alongside academic performance, and providing empirical evidence from a developing-country higher education context, this study contributes to the growing body of literature on technology-enhanced learning in architectural education. In addition, the findings offer practical implications for curriculum development, instructional design, and the effective integration of simulation technologies into technical architecture courses.

RESEARCH METHODOLOGY

Research Design

This study was applied in terms of its purpose and employed a quasi-experimental pretest–posttest design with a control group for data collection. According to Sarmad (2022), a type of quasi-experimental design in which participants are not randomly selected or assigned to groups is referred to as a non-equivalent control group pretest–posttest design. This design was selected because random assignment of students to groups was not feasible within the educational setting.

When researchers aim to empirically evaluate the effectiveness of an educational intervention, the use of experimental and control groups is considered one of the most rigorous methodological approaches. The experimental group is the group to which the intervention is administered, whereas the control group does not receive the intervention and serves as a benchmark for comparison. In this design, the dependent variable is measured before the implementation of the intervention (pretest) and again after the intervention has been completed (posttest). Comparing the outcomes of the two groups enables researchers to determine whether the observed changes can be attributed to the intervention. Therefore, the control group provides a reference point against which the effectiveness of the intervention implemented in the experimental group can be assessed.

Participants

The study population consisted of undergraduate architecture students enrolled in the Building Structures course at the Islamic Azad University of Urmia during the academic semester in which the study was conducted. A total of 50 students participated in the research and were assigned to either an experimental group (n = 25) or a control group (n = 25).

Participants were selected using convenience sampling from students who had enrolled in the Building Structures course. According to Cohen, Manion, and Morrison (2011), a minimum sample size of 15 participants per subgroup is generally considered adequate for experimental and quasi-experimental educational research. Therefore, the sample size employed in the present study exceeded the minimum recommended threshold.

To ensure equivalence between the groups prior to the intervention, students participated in three introductory sessions covering the fundamental concepts of Building Structures. Subsequently, a baseline knowledge test was administered. Independent-samples t-test results indicated no statistically significant difference between the experimental and control groups regarding prior knowledge of Building Structures concepts. Therefore, the two groups were considered comparable before the intervention. Table 1 presents the descriptive statistics of the baseline knowledge assessment.

Research Instrument

Academic motivation was measured using the Hermans Achievement Motivation Test (AMT). The instrument consists of 29 incomplete-statement items scored on a four-point Likert-type scale.

Each item presents four response alternatives, scored from 1 to 4. Several items are reverse-coded. Higher total scores indicate higher levels of achievement motivation. For items 1, 4, 9, 10, 14, 15, 16, 20, 23, 27, 28, and 29, responses are scored in ascending order from 1 to 4, whereas the remaining items are scored in reverse order. Total scores range from 29 to 116.

Hermans reported item-total correlation coefficients ranging from 0.30 to 0.57, indicating acceptable construct validity. The instrument has been widely used in educational and psychological research and has demonstrated satisfactory psychometric properties.

In the present study, internal consistency reliability was assessed using Cronbach’s alpha coefficient, yielding a value of 0.79, which indicates satisfactory reliability.

Simulation-Based Instructional Intervention

The intervention was conducted over an eleven-week period, with one instructional session held each week. Each session lasted approximately 90 minutes.

To eliminate instructor-related bias, both groups were taught by the same instructor. Furthermore, the learning objectives, course content, assessment procedures, instructional duration, and expected learning outcomes were identical for both groups. The only difference between the groups concerned the instructional delivery method.

Students in the experimental group received instruction through an interactive computer simulation environment. The simulation enabled students to visualize structural components, building service systems, and the interactions among building subsystems within a dynamic three-dimensional environment. Students were able to manipulate variables, explore alternative design scenarios, observe system responses in real time, and evaluate the consequences of different technical decisions.

The instructional procedure consisted of four sequential phases:

1. **Conceptual Explanation:** Introduction of theoretical concepts and technical principles by the instructor.
2. **Simulation-Based Exploration:** Students interacted with simulation models to visualize and examine Building Structures and their performance.
3. **Guided Problem-Solving Activities:** Students completed structured tasks requiring analysis, decision-making, and interpretation of simulation outputs.
4. **Discussion and Feedback:** Group discussions were conducted to reflect on learning experiences and receive instructor feedback.

In contrast, students in the control group received conventional lecture-based instruction. Teaching methods in this group consisted of instructor explanations, PowerPoint presentations, and classroom discussions without the use of interactive simulation technologies (see Figure 1).

Data Collection Procedure

Academic motivation was measured twice during the study. The first measurement (pretest) was conducted before the implementation of the instructional intervention, and the second measurement (posttest) was administered immediately after completion of the course.

In addition to motivation data, students' final examination scores were collected as an indicator of academic achievement and learning performance.

To complement quantitative findings, classroom observations were conducted throughout the semester to document student participation, engagement, and interaction during instructional activities.

Fig 1. Instruction Employing the Interactive Simulation Method

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS).

Descriptive statistics, including means and standard deviations, were calculated for all study variables. Prior to conducting inferential analyses, the assumptions of normality, homogeneity of variances, and homogeneity of regression slopes were examined.

Analysis of Covariance (ANCOVA) was employed to compare posttest motivation scores between the experimental and control groups while statistically controlling for pretest differences. ANCOVA was selected because it allows adjustment for baseline variability and provides a more accurate estimate of treatment effects.

Furthermore, ANCOVA was used to compare final examination scores between groups. Effect sizes were calculated to determine the practical significance of observed differences, following Cohen et al. (2013) guidelines for interpreting effect magnitude. Statistical significance was evaluated at the 0.05 level.

The research process is presented in Figure 2.

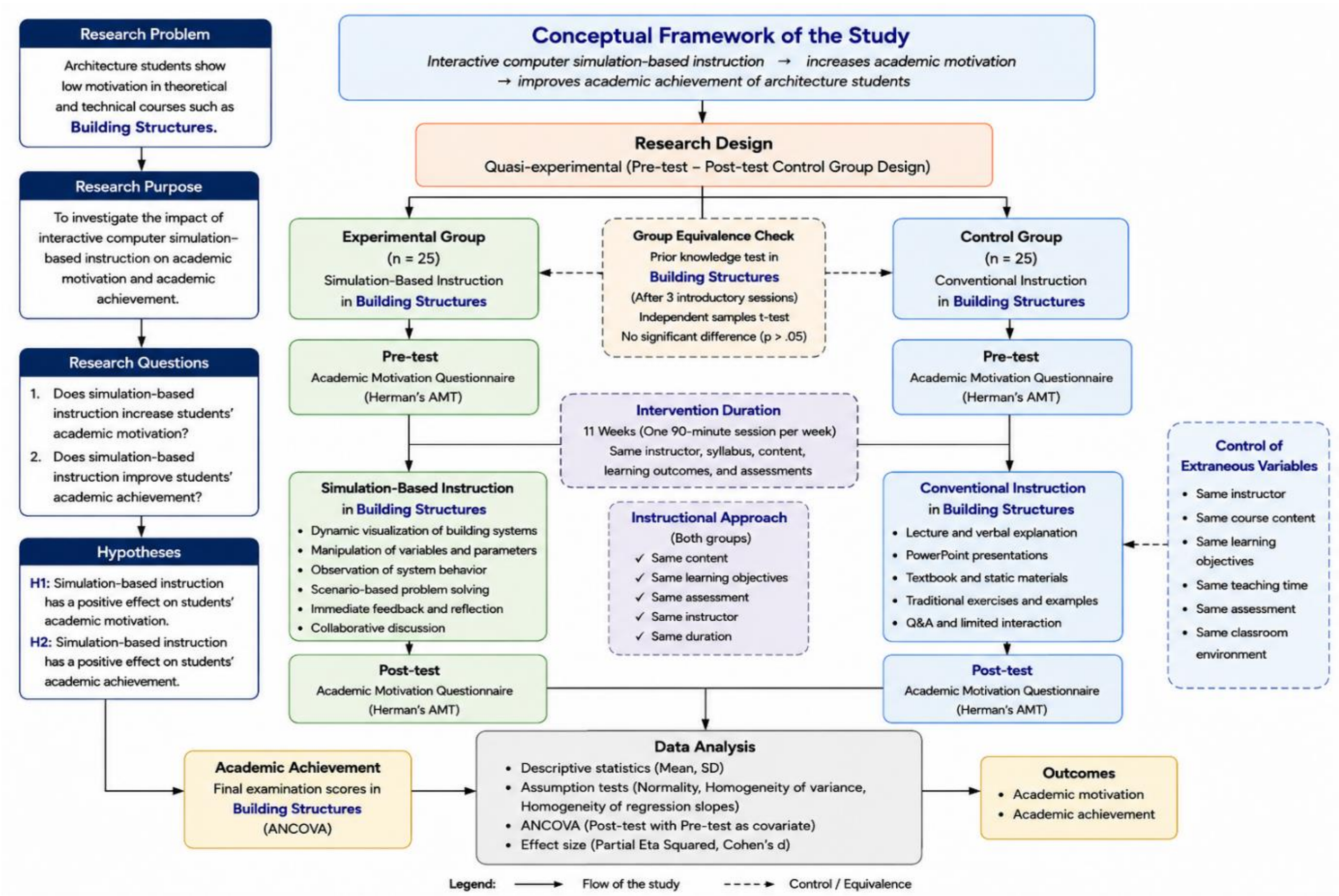

Fig 2. Theoretical Framework

FINDINGS

According to Table 1, the mean score of the experimental group was 16.23 (SD = 1.82), while the mean score of the control group was 16.26 (SD = 2.02). An independent samples t-test showed no statistically significant difference between the two groups in their baseline level of knowledge ($t = -0.06$, $p > .05$). Therefore, the two groups were considered homogeneous prior to the intervention.

The scores reported in Table 1 represent students' performance on a preliminary Building Structures knowledge test administered after the first three introductory sessions. The test was used to verify the equivalence of the experimental and control groups prior to the intervention. An independent-samples t-test confirmed that no statistically significant difference existed between the two groups.

After collecting and coding the questionnaire data, statistical analyses were conducted using SPSS software. Data analysis was performed at both descriptive and inferential levels. Descriptive statistics included means and standard deviations, while inferential statistics were conducted using analysis of covariance (ANCOVA) after examining the required statistical assumptions.

Table 2 presents the descriptive statistics for academic achievement motivation in the pretest and posttest phases. As shown, there was little difference between the groups at the pretest stage. However, following the intervention, the experimental group demonstrated a substantial increase in motivation scores compared with the control group.

To facilitate interpretation of the intervention effects, the changes in motivation scores from pretest to posttest were calculated and are presented in Table 3.

Table 1. Comparison of Pretest Knowledge Scores in the Experimental and Control Groups

Standard deviation	Mean	Number	Name	Group
1.82	16.23	25	A	Experimental
2.02	16.26	25	B	Control

Table 2. Means and Standard Deviations of Academic Achievement Motivation Scores in the Pretest and Posttest Phases

Control group	Experimental group		
80.58	80.78	Mean	Pretest
10.21	11.02	Standard deviation (SD)	
80.61	92.78	Mean	Posttest
10.11	7.02	Standard deviation (SD)	

Table 3. Changes in Academic Achievement Motivation Scores

Percentage Change	Mean Change	Posttest Mean	Pretest Mean	Group
14.86%	+12.00	92.78	80.78	Experimental
0.04%	+0.03	80.61	80.58	Control

Given that 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-Wilk test indicated that the significance level was higher than 0.05. (W=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 0.87. Therefore, the significance level exceeded 0.05, and the assumption of homogeneity of variances is confirmed.

In the examination of the homogeneity of the regression slope grades, an F value of 1.36 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).

After ensuring the homogeneity of the variables, a covariance test was performed, and Table 4 shows the test results for comparing motivation progress in the post-test phase. The table results and an F value of 97.216, 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 that of trained using conventional methods.

The ANCOVA results revealed a statistically significant effect of the instructional method on posttest motivation scores after controlling for pretest differences, $F(1,47) = 103.97$, $p < .001$. The partial eta squared value ($\eta^2 = 0.672$) indicates that approximately 67.2% of the variance in posttest motivation scores was explained by the intervention. This represents a very large effect size.

Following completion of the educational intervention, students in both groups participated in a final examination at the end of the semester. The descriptive statistics for the final examination scores are presented in Table 5.

The results indicate that students in the experimental group achieved higher final examination scores than students in the control group.

To compare the academic performance of the two groups while controlling for baseline differences, ANCOVA was conducted. The results are presented in Table 6.

Table 4. Results of ANCOVA for Academic Achievement Motivation

p-value	Partial η^2	F value	Mean of squares	Degrees of freedom	Sum of squares	Source
< .001	0.754	157.05	2610.112	1	2610.112	Pretest
< .001	0.672	103.97	1728.015	1	1728.015	Group
–	–	–	17.755	44	781.241	Error

Table 5. Descriptive Statistics of Final Examination Scores

Standard deviation	Mean	Number	Name	Group
1.91	17.12	25	A	Experimental
2.05	16.28	25	B	Control

Table 6. ANCOVA Results for Final Examination Scores

Variable	F	p-value	Cohen’s d	Interpretation
Group	5.29	.025	0.42	Moderate effect

The results demonstrated a statistically significant difference between the two groups in final examination performance, F (1,47) = 5.29, p = .025. Students who received simulation-based instruction achieved significantly higher academic performance than those who received conventional instruction. The effect size (Cohen's d = 0.42) indicates a moderate educational effect according to Cohen's criteria.

Overall, the findings suggest that simulation-based education significantly improved both academic achievement motivation and academic performance among students compared with traditional instructional methods.

DISCUSSION

The present study examined the effectiveness of interactive computer simulation-based instruction in enhancing the academic motivation of architecture students enrolled in a Building Structures course. The findings revealed that students who participated in simulation-based instruction demonstrated significantly higher levels of academic motivation than those who received conventional lecture-based instruction. The ANCOVA results further confirmed that these differences remained statistically significant after controlling for pre-test scores, indicating that the observed improvements were attributable to the instructional intervention rather than to pre-existing differences between the groups.

These findings contribute to the growing body of evidence indicating that technology-enhanced learning environments can positively influence both motivational and cognitive outcomes. Unlike many previous investigations conducted in broader educational contexts, the present study focused specifically on Building Structures education within an undergraduate architecture program. This context is particularly important because structural and building-system courses are often perceived by architecture students as abstract, technically demanding, and difficult to visualize. Consequently, sustaining student motivation in such courses has long represented a significant pedagogical challenge.

One possible explanation for the motivational gains observed among students in the experimental group lies in the visual, interactive, and experiential nature of simulation-based learning environments. Traditional instruction in building systems and structural concepts typically relies on static diagrams, verbal explanations, and two-dimensional representations. Although these approaches may effectively communicate theoretical information, they often fail to convey the dynamic relationships among building components and systems. In contrast, the simulation environment used in this study enabled students to visualize structural elements, explore interactions among building systems, manipulate variables, and immediately observe the outcomes of their decisions. Such opportunities for active exploration likely enhanced students' understanding and perceived competence, thereby strengthening their intrinsic motivation to learn.

The findings may also be interpreted through the lens of Self-Determination Theory, which posits that educational environments supporting autonomy, competence, and relatedness foster stronger intrinsic motivation. The simulation-based instructional approach employed in this study encouraged students to become active participants in the learning process rather than passive recipients of information. Through experimentation, exploration, and immediate feedback, students were able to construct knowledge independently and monitor their own learning progress. These characteristics likely contributed to enhanced perceptions of mastery and self-efficacy, both of which are well-established predictors of academic motivation.

From a constructivist perspective, the results further support the view that meaningful learning occurs when learners actively construct knowledge through interaction with their environment. Simulation technologies provide opportunities for experiential learning by allowing students to engage directly with virtual representations of real-world systems. Rather than memorizing theoretical concepts, students can test assumptions, observe consequences, and refine their understanding through iterative exploration. Such learning experiences foster deeper cognitive engagement and are therefore more likely to generate positive motivational outcomes.

The present findings are consistent with previous studies conducted in architecture, engineering, and educational technology contexts. Kwon (2005) reported that virtual environments enhanced students' spatial perception and understanding of architectural spaces. Similarly, Darwish et al. (2023) found that extended reality technologies substantially improved spatial abilities in architectural design education. The current study extends this body of literature by demonstrating that simulation technologies contribute not only to cognitive development but also to motivational enhancement within architectural education.

Support for these findings can also be found in recent systematic reviews and meta-analyses. Sirror et al. (2021), Al-Ansi et al. (2023), and Taherysayah et al. (2024) concluded that virtual and simulation-based educational environments consistently improve learner engagement, interaction, and overall educational effectiveness across diverse disciplines. The present study corroborates these conclusions while providing evidence from a Building Structures course, a context that has received relatively limited attention in previous research.

Another important interpretation concerns the role of student engagement as a mediating mechanism between instructional methods and motivational outcomes. Educational research consistently suggests that engagement serves as a critical pathway through which instructional strategies influence learning outcomes. Fuertes et al. (2023) reported strong relationships among engagement, motivation, and academic achievement, while Skinner et al. (2008) emphasized that emotionally and behaviorally engaged students are more likely to demonstrate persistence and sustained academic motivation. Consistent with these findings, classroom observations conducted during the intervention indicated that students in the simulation-based environment participated more actively in discussions, asked more questions, and displayed greater enthusiasm toward learning activities than students in the control group. These observations provide qualitative support for the quantitative results obtained in this study.

Although academic motivation constituted the primary focus of the present investigation, the findings also revealed significantly higher final examination scores among students in the experimental group. This result is consistent with extensive evidence demonstrating that motivation is a powerful predictor of academic achievement. Previous studies by Sadeghi et al. (2022), Fuertes et al. (2023), and other scholars have consistently reported positive associations between academic motivation and educational performance. Therefore, the improvements in academic achievement observed among students receiving simulation-based instruction may be partially explained by the motivational benefits generated through the intervention.

A notable contribution of this study lies in addressing an important gap within the existing literature. Most previous research has examined virtual reality, augmented reality, and simulation technologies primarily as tools for enhancing spatial visualization, technical competence, and cognitive performance. Comparatively little attention has been devoted to their influence on motivational outcomes within architectural education, particularly in technically oriented courses such as Building Structures. Moreover, many previous investigations have focused predominantly on design studios rather than engineering-related architectural subjects. By examining academic motivation within a Building Structures course, the present study broadens current understanding of how simulation technologies can support learning in domains that students often perceive as challenging and less engaging.

The study also contributes methodologically by providing a clearly structured and replicable simulation-based instructional framework. One limitation frequently identified in the simulation-learning literature is the inadequate description of intervention procedures, which restricts reproducibility and practical implementation. In contrast, the present study explicitly documented the instructional procedures, duration of implementation, simulation activities, instructor responsibilities, and comparison conditions. Such methodological transparency enhances the practical value of the findings and facilitates future replication studies.

From a practical perspective, several implications emerge. First, simulation-based instruction appears to be an effective strategy for enhancing student motivation in technically demanding architecture courses. Second, architecture programs seeking to modernize their curricula may benefit from integrating simulation technologies alongside conventional instructional approaches. Third, simulation environments can support deeper conceptual understanding while simultaneously promoting engagement, persistence, and positive learning experiences.

These implications are particularly relevant in light of the ongoing digital transformation of higher education. Emerging technologies such as virtual reality, augmented reality, mixed reality, Building Information Modeling (BIM), artificial intelligence, and digital simulation platforms are increasingly reshaping architectural education worldwide. Scholars including Soliman et al. (2019), Kharvari and Kaiser (2022), Ramadhan et al. (2024), Kee et al. (2024), and Kumar and Janardhan (2023) have argued that future architecture curricula must incorporate advanced digital technologies to prepare students for increasingly technology-driven professional environments. The findings of the present study provide empirical support for this transition by demonstrating measurable educational benefits associated with simulation-based learning.

Despite its contributions, several limitations should be acknowledged. First, the study was conducted at a single institution, which may limit the generalizability of the findings to other educational contexts. Second, although the sample size met established methodological recommendations for quasi-experimental research, larger samples would improve statistical power and external validity. Third, the study focused on short-term motivational outcomes measured immediately after the intervention; therefore, future longitudinal studies are needed to determine whether the observed motivational gains are sustained over time. Finally, although simulation-based instruction produced significant benefits, the study did not compare simulation technologies with other emerging educational tools, such as immersive virtual reality, augmented reality, or mixed-reality systems.

Future research should therefore investigate the comparative effectiveness of different immersive technologies across architectural education contexts. In addition, researchers should examine other important psychological and educational variables, including self-efficacy, creativity, critical thinking, problem-solving ability, learning engagement, and professional identity development. Multi-institutional studies employing larger and more diverse samples would further strengthen the evidence base. Finally, qualitative investigations could provide richer insights into students’ experiences, perceptions, and learning processes within simulation-based educational environments.

CONCLUSION

This study examined the impact of interactive computer simulation-based instruction on the academic motivation of architecture students enrolled in a Building Structures course. The findings demonstrated that students who participated in simulation-based learning achieved significantly higher levels of academic motivation compared with students who received conventional instruction. After controlling for pre-existing differences through ANCOVA, the positive effect of the intervention remained statistically significant, indicating that simulation-based instruction was an influential factor in enhancing student motivation.

The study contributes to the literature in several important ways. First, it shifts attention from the frequently investigated cognitive and spatial benefits of simulation technologies toward their motivational effects within architectural education. Second, it provides empirical evidence from a Building Structures course, a context that has received limited attention in previous simulation-based educational research. Third, it offers a detailed description of the instructional intervention, thereby enhancing the practical applicability and replicability of the research.

The findings suggest that simulation-based instruction can create more engaging and meaningful learning experiences by facilitating active participation, immediate feedback, conceptual visualization, and experiential learning. These characteristics appear to strengthen students' interest, engagement, and willingness to invest effort in academic activities. Consequently, simulation technologies may represent a valuable pedagogical tool for addressing motivational challenges frequently encountered in technically oriented architecture courses.

Given the rapid digital transformation of architectural education and professional practice, integrating simulation technologies into architecture curricula may provide substantial educational benefits. Nevertheless, the findings should be interpreted within the limitations of the study, and further research is needed to investigate long-term effects, broader educational outcomes, and applications across diverse institutional contexts.

Overall, the results indicate that interactive computer simulation constitutes an effective instructional approach for enhancing academic motivation among architecture students studying Building Structures and can serve as a meaningful complement to traditional teaching methods in higher education.

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