Integrating Advanced Building Information Modeling and Augmented Reality in Civil Engineering Education: Perceptions, Benefits, and Challenges

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Abstract- This study examines the perceptions of students and faculty regarding the integration of Building Information Modeling (BIM) and Augmented Reality (AR) technologies in civil engineering education. The research explores the potential of these technologies to enhance learning outcomes and practical skills. Data from surveys were analyzed using descriptive statistics, reliability analysis, and exploratory factor analysis to assess the validity and internal consistency of the measurement scale. Results reveal a consensus among participants that AR-based training is more engaging than traditional methods and improves the understanding of BIM structures. Participants reported that AR provides a realistic and immersive training experience, increasing their confidence in applying advanced BIM practices. The high reliability and unidimensionality of the measurement scale, as confirmed by EFA, further support the effectiveness of BIM and AR in civil engineering education. While acknowledging limitations such as sample size and reliance on self-reported perceptions, the findings suggest that integrating BIM and AR into civil engineering curricula can create more engaging, effective, and relevant learning experiences for students, preparing them for the demands of the modern construction industry. The study recommends a dual approach focusing on curriculum enhancements and practical training, as well as further research to objectively measure the impact of BIM and AR on student learning outcomes and explore factors influencing the adoption of these technologies. This research contributes to the growing body of knowledge on the application of BIM and AR in education, providing a foundation for future research and implementation efforts.

Indexed Terms- Building Information Modeling, Augmented Reality, Civil Engineering Education, NEUST Technology-Enhanced Learning.

I. INTRODUCTION

Despite the growing relevance of Building Information Modeling and Augmented Reality in global construction practices, their integration into the construction sector in the Philippines remains inconsistent and underdeveloped, hindering the potential for innovation and efficiency gains within the industry. Traditional teaching methods often rely on abstract concepts and two-dimensional representations, which can be challenging for students. The integration of BIM and AR aims to address these challenges by visualizing designs and processes, helping students more easily understand complex engineering principles and their practical implications (Zou & Zhang, 2021). However, the integration of advanced BIM and AR technologies into the civil engineering curriculum in the Philippines is still limited. Furthermore, there is a gap in existing research regarding the perceptions and effectiveness of BIM and AR in this context. A comprehensive investigation into the academic, technical, and institutional requirements for effective BIM and AR implementation is needed (Besné et al., 2021). Effective integration necessitates restructuring curricula to include both theoretical knowledge and practical experience, introducing BIM and AR concepts early in the academic program to establish a solid foundational understanding (Ghanem, 2022). A comprehensive framework for training and education is essential to facilitate the widespread adoption and implementation of AI-integrated BIM practices in the construction sector (Rane, 2023). It is important to study the integration of BIM and AR in civil engineering education because it enhances learning and prepares students for the modern construction industry (Diao & Shih, 2019). This ensures students develop a holistic understanding of BIM and AR, preparing them to be competent and innovative civil engineers in the digital age.

A. Literature Review

The integration of BIM and AR in civil engineering education holds immense potential for enhancing student learning, improving skills development, and preparing graduates for the demands of the modern construction industry (Ashour et al., 2022; Ghanem, 2022). However, realizing this potential requires careful planning, investment, and collaboration among academic institutions, industry partners, and technology providers. Several studies have highlighted the limitations of adopting VR/AR in educational systems, attributing them to factors such as high costs, lack of localized content, insufficient teacher training, and sociocultural resistance to new technologies (Mondal & Mondal, 2025). These challenges are further compounded by infrastructure limitations, policy and institutional barriers, and equity issues (Mondal & Mondal, 2025). Despite these obstacles, the integration of VR/AR into education has demonstrated the capacity to enhance student involvement, encourage immersive learning experiences, and boost knowledge retention (Vats & Joshi, 2023). Industry professionals can provide valuable insights and guidance on the latest trends and best practices in BIM and VR/AR, ensuring that the curriculum remains relevant and up-to-date. Moreover, lifelong learning, especially for engineers seeking career changes or interdisciplinary collaboration can be enhanced through HMD VR (Huang & Roscoe, 2021). Effective deployment of Virtual Reality/Augmented Reality requires collaboration among educators, policymakers, and business leaders to enable access, develop pedagogical frameworks, and construct teacher training programs (Thangavel, 2025).

B. Conceptual Framework

The conceptual framework presented in Figure 1 illustrates a systematic input-process-output model that guides this study's investigation of civil engineering students' and faculty's perceptions toward Building Information Modeling (BIM) and Augmented Reality (AR) integration in educational settings. The Input component encompasses demographic variables and perception data collected through an 8-item Likert-scale survey questionnaire administered to civil engineering students and faculty at NEUST. The Data Analysis Process component represents the comprehensive statistical procedures employed to ensure data quality and extract meaningful insights, including reliability assessment through Cronbach's alpha, descriptive statistical analysis, and exploratory factor analysis with Kaiser-Meyer-Olkin and Bartlett's tests to validate the measurement scale's psychometric properties. The Research Findings component presents the empirical outcomes that demonstrate strong statistical evidence supporting the reliability, validity, and positive perceptions of BIM-AR integration, ultimately contributing to evidence-based recommendations for technology-enhanced CE education.

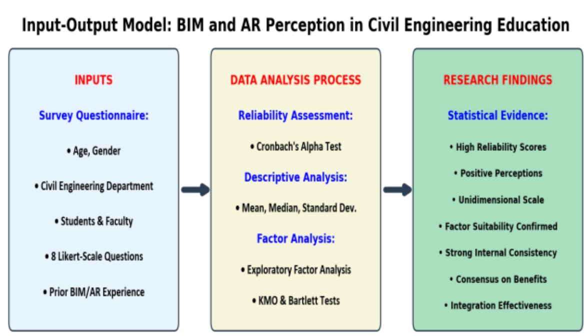


Fig.1. Conceptual Framework

C. Objectives

- To assess the perceived benefits of using advanced BIM and AR in enhancing engagement and understanding in civil engineering education.
- To evaluate the perceived effectiveness of AR-based training in improving practical skills and confidence in applying advanced BIM practices.

- To determine the reliability and validity of a measurement scale designed to assess perceptions of BIM and AR in civil engineering education.
- To explore the potential of AR-based assessments in evaluating practical BIM knowledge.
- To identify potential challenges and opportunities associated with the integration of BIM and AR in civil engineering curricula.

D. Significance of the Study

This study's significance lies in its empirical validation of integrating advanced Building Information Modeling and Augmented Reality into civil engineering education, demonstrating enhanced learning outcomes, practical skill development, and student engagement. By confirming the reliability and unidimensionality of the measurement scale, the research provides a foundation for future studies and practical implementation efforts in modernizing engineering curricula to align with industry demands. The findings offer actionable insights for educators and curriculum developers seeking to create relevant learning experiences, bridge the gap between theory and practice, and equip students with essential competencies for the construction industry. Furthermore, the study contributes to the limited literature on BIM and AR in civil engineering education in the Philippines, addressing the need for innovative teaching methods and technology integration to enhance student understanding and prepare them for professional success.

E. Scope and Limitations of the Study

This study focuses on exploring the perceptions of civil engineering students and faculty towards the integration of BIM and AR technologies in education. The scope is limited to assessing subjective views on the potential benefits, engagement, and effectiveness of these tools based on a quantitative analysis using a Likert-scale questionnaire. The study's limitations include a reliance on self-reported data, which may be subject to bias, and a sample size that may restrict the generalizability of the findings. Future research should consider expanding the sample to include a more diverse range of institutions and employ objective measures, such as academic performance, practical tests, or project evaluations, to evaluate the actual impact of BIM and AR on learning outcomes.

II. METHODS AND PROCEDURES

A. Research Design

This study utilized a quantitative, descriptive research design to investigate the perceptions of civil engineering students and faculty at Nueva Ecija University of Science and Technology regarding the integration of Building Information Modeling and Virtual/Augmented Reality into the curriculum. A descriptive approach was deemed appropriate to provide a comprehensive overview of the existing levels of awareness, perceived advantages, and obstacles associated with BIM and AR implementation. Data was gathered through a structured questionnaire comprising 5-point Likert-scale items, which were designed to evaluate key constructs such as awareness, perceived benefits, challenges, and effectiveness of BIM and AR in civil engineering education.

B. Locale of the Study

The study took place at Nueva Ecija University of Science and Technology's Sumacab Campus, a state-funded institution dedicated to quality education in science and technology. Located in Sumacab, Cabanatuan City, Nueva Ecija, Philippines. The university serves as a regional hub for learning and innovation. Its location within a growing urban center allows access to diverse resources and opportunities for collaboration with industry partners. The university's commitment to technological innovation positions it as an ideal setting for conducting pioneering research on the applications of BIM and AR in civil engineering education, with the goal of producing graduates who are competitive on a global scale and prepared to address the demands of the modern workforce.

C. Participants and Data Collection

The participants in this study were civil engineering students and faculty members at Nueva Ecija University of Science and Technology. A convenience sampling method was used to recruit individuals who had either taken or taught subjects related to BIM. This ensured representation from individuals with direct exposure to relevant subjects, strengthening the study's focus on evaluating perceptions within a knowledgeable group. Participants were invited to complete the survey via email or in person. A total of 40 participants completed the questionnaire, comprising 35 students and 5 faculty members. Among the students, 87.5% were between 18 and 21 years old. The faculty members had an average of 3 years of teaching BIM. Approximately 87.5% of the participants had no prior experience with AR, while only 12.5% had experience with it once. Only one participant was very familiar with AR, 19 were somewhat familiar, 12 were neutral, three were not very familiar, and five were not familiar at all. Before data collection, all participants provided informed consent. Participation was voluntary, and participants were guaranteed anonymity and confidentiality.

D. Instruments

The questionnaire consisted of 16 items designed to measure awareness, perceived benefits, challenges, and effectiveness of BIM and AR in civil engineering education. 8 Items were measured on a 5-point Likert scale. The questionnaire was adapted from existing instruments in the literature and modified to suit the specific context of this study. A pilot test was conducted with a small group of students and faculty to ensure face validity and clarity of the items. The reliability of the scales was assessed using Cronbach's alpha. The Likert Scale items include: Q1 - Advanced BIM and AR-based training is more engaging than traditional methods. Q2 - AR can help me better understand BIM structures and systems. Q3 - AR training looks realistic and immersive. Q4 - I feel more confident applying advanced BIM practices with AR training. Q5 - I would recommend AR-based BIM training to others in my field. Q6 - AR training improves the retention of advanced BIM knowledge better than lectures. Q7 - I find AR-based assessments more effective in testing my BIM practical knowledge than written exams. Q8 - AR-based training is an effective bridge between advanced BIM theory and practice.

E. Data Analysis Technique

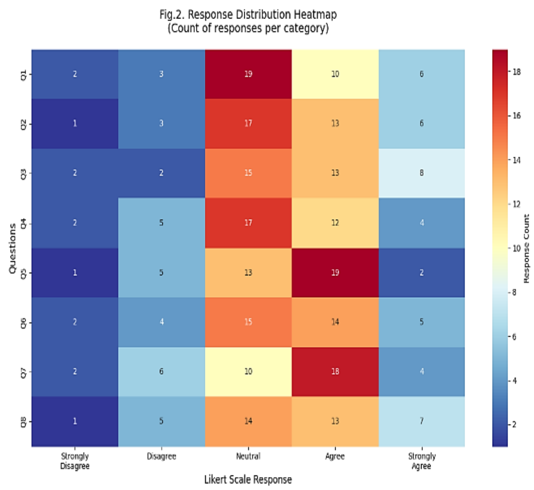
Before analysis, the data were prepared and cleaned using Microsoft Excel. Cronbach's alpha was calculated to assess the internal consistency of the scales. Item-deleted analysis was conducted to identify items that may be reducing the reliability of the scales. Descriptive statistics (means, medians, standard deviations) were calculated for each item and scale to summarize the central tendency and variability of responses. Exploratory factor analysis was conducted to identify underlying factors or dimensions. The Kaiser-Meyer-Olkin test and Bartlett's test of sphericity were used to assess the suitability of the data for factor analysis. Factors were extracted using principal axis factoring, and varimax rotation was used to improve interpretability. Only factors with eigenvalues greater than 1 were retained. Effect sizes were calculated to quantify the magnitude of the differences. All statistical analyses were conducted using Python Version 3.13 through PyCharm.

F. Ethical Considerations

The study adhered to the ethical standards outlined in the Data Privacy Act of 2012. All personal data were kept confidential, and participants' identities remained anonymous. Participation was voluntary, and respondents could withdraw at any time. Data were securely stored and used solely for academic purposes.

III. RESULTS AND DISCUSSIONS

The response distribution (refer to Figure 2) across the questionnaire items indicates a generally positive perception of integrating BIM and AR into CE education. Participants' responses tended to be above neutral, demonstrating a favorable attitude, with a narrow range of responses demonstrating strong internal consistency across the items.



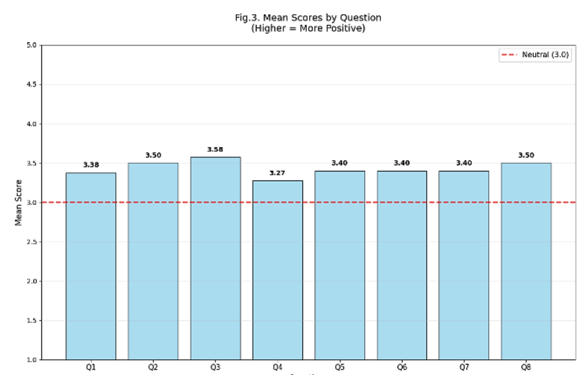
To evaluate the consistency of the Likert-scale questions, a reliability analysis was performed. Cronbach's alpha was utilized to measure the internal consistency of all variables. The overall scale demonstrated excellent reliability, with a Cronbach's alpha of 0.989. Furthermore, item-deleted analysis indicated that the removal of any item would not increase the alpha value, suggesting that no items were significantly compromising the scale's reliability.

The descriptive analysis reveals eight variables with highly consistent psychometric properties, demonstrating means clustered around 3.4 and standard deviations between 0.871-1.035 (refer to Table 1), indicating moderate variability and adequate response discrimination. The close alignment between means and medians across Q1-Q7 suggests approximately normal distributions with minimal skewness, while Q8's perfect mean-median convergence indicates optimal distributional symmetry. The narrow range of both central tendency measures and variability indices demonstrates strong internal consistency and homogeneity across items, suggesting these variables likely measure related constructs within the same theoretical framework. These results indicate a shared understanding and perception among participants regarding the potential of BIM and AR in civil engineering education. This consensus strengthens the argument for integrating these technologies into the curriculum to enhance learning outcomes and practical skills.

Table 1: DESCRIPTIVE STATISTICS

Variable	Mean	Median	Std Dev
Q1	3.375	3	1.005
Q2	3.500	3	0.934
Q3	3.575	4	1.035
Q4	3.275	3	0.987
Q5	3.400	4	0.871
Q6	3.400	3	1.008
Q7	3.400	4	1.033
Q8	3.500	4	1.013

The visualization of mean scores (refer to Figure 3) reveals a notable consistency across all eight questions, with values tightly clustered around 3.4-3.5, all slightly above the neutral midpoint. This uniform pattern suggests balanced item difficulty, confirming the absence of extreme endorsement patterns that could compromise scale reliability. The consistent positioning above neutral indicates a marginally positive response tendency across all items, while the narrow range demonstrates excellent internal consistency. This homogeneous response pattern supports the single-factor structure and validates the appropriateness of computing composite mean scores for the overall construct.



Exploratory factor analysis identified three latent factors within the dataset. The Kaiser-Meyer-Olkin value of 0.914 and a significant Bartlett's test of sphericity confirmed the suitability of the data for factor analysis. Examination of the scree plot (refer to Figure 4) revealed a distinct "elbow" pattern, with Factor 1 exhibiting a notably high eigenvalue of approximately 7.3, followed by a sharp decline to values below 1.0 for all subsequent factors. This pattern provides strong support for a single-factor solution, as only Factor 1 surpasses the Kaiser criterion threshold. The steep decline between Factors 1 and 2, followed by a relatively flat trajectory, indicates that extracting additional factors would not substantially enhance the model's explanatory power. This observation aligns with the factor loadings matrix results, further reinforcing the unidimensional nature of the measurement scale.

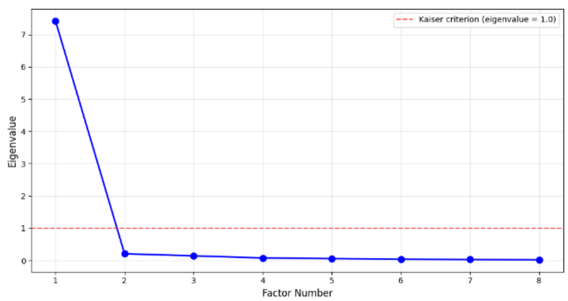


Fig.4. Scree Plot for Factor Analysis
(Elbow indicates optimal number of factors)

The factor loadings matrix reveals a robust single-factor solution, with all eight variables (refer to Figure 5) demonstrating exceptionally high loadings on Factor 1. The uniformly strong factor loadings indicate that these items measure a single, well-defined latent construct with minimal measurement error. The narrow range of loadings suggests an equal contribution of each item to the underlying factor, supporting the creation of a reliable composite scale. This unidimensional structure validates the theoretical framework and confirms that all variables can be appropriately combined into a single factor score for subsequent analyses. These findings enhance the statistical validity of the scale, ensuring that it accurately measures the intended constructs related to BIM and AR integration in CE education.

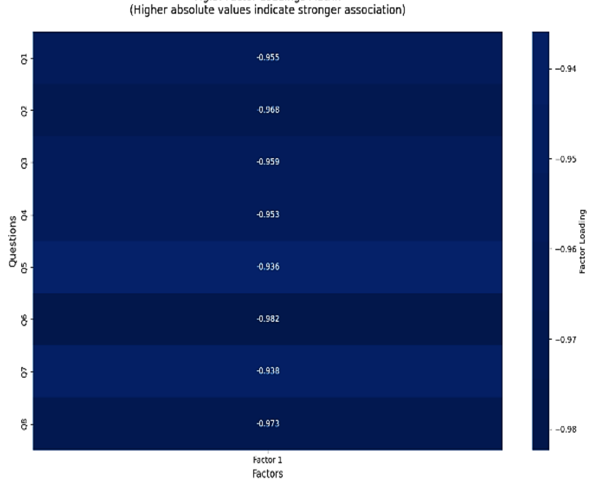


Fig.5. Factor Loadings Matrix
(Higher absolute values indicate stronger association)

CONCLUSION

This study investigated the perceptions of students and faculty towards the integration of BIM and AR technologies in civil engineering education. The findings provide strong evidence for the potential benefits of these technologies in enhancing learning outcomes and practical skills. The high reliability and unidimensionality of the measurement scale, coupled with positive participant perceptions, suggest that BIM and AR can effectively engage students, improve their understanding of complex concepts, and bridge the gap between theory and practice.

Specifically, the study revealed a consensus among participants that AR-based training is more engaging than traditional methods, improves the understanding of BIM structures, provides a realistic and immersive training experience, and increases confidence in applying advanced BIM practices. Participants also indicated a willingness to recommend AR-based BIM training to others, suggesting a strong belief in its value and effectiveness.

While this study provides valuable insights, it is important to acknowledge its limitations, including the sample size and reliance on self-reported perceptions. Future research should focus on objectively measuring the impact of BIM and AR on student learning outcomes and exploring the factors that influence the adoption of these technologies in civil engineering education.

Despite these limitations, the findings of this study support the integration of BIM and AR into civil engineering curricula. By embracing these innovative technologies, educators can create more engaging, effective, and relevant learning experiences for students, preparing them for the demands of the modern construction industry.

In summary, this research contributes to the growing body of knowledge on the application of BIM and AR in education, providing a foundation for future research and implementation efforts. The positive perceptions and demonstrated potential of these technologies warrant further exploration and investment in their integration into civil engineering education.

RECOMMENDATIONS

To facilitate the effective integration of BIM and AR technologies into civil engineering education, a dual approach is recommended, focusing on curriculum enhancements and practical training. Integrate BIM and AR modules into existing courses to ensure broad exposure, provide hands-on training opportunities, and invest in comprehensive faculty development programs. Establishing strong collaborations with industry partners can offer students invaluable real-world experiences, bridging the gap between academic learning and practical application. The development and implementation of AR-based assessments can provide a more engaging and effective means of evaluating students' practical BIM knowledge and skills. In addition to these practical steps, future research should address the limitations of this study by expanding sample diversity to include a broader range of institutions and participant demographics. Incorporating objective measures, such as evaluating performance on practical projects or tests, will provide a more comprehensive assessment of the impact of BIM and AR on student learning outcomes. Consider exploring the factors that influence the adoption of these technologies in civil engineering education. This could involve investigating the impact of institutional support, available resources, and faculty attitudes on the successful integration of BIM and AR. Further investigation into the cost-effectiveness of BIM and AR implementation would also be valuable in justifying the investment in these technologies. By addressing these areas, future research can contribute to a more comprehensive understanding of the potential of BIM and AR in transforming civil engineering education.

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