Integrating BIM into Sustainable Design: Perception and Awareness of Architecture and Construction Management Students

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Abstract

Integrating Building Information Modeling (BIM) technology into Sustainable Design (SD) can significantly improve Architectural, Engineering, and Construction (AEC) practices. However, there is a concern that students may not have a practical understanding and application of BIM principles in Sustainable Design projects despite an increasing emphasis on BIM in academic curricula. This discrepancy raises important questions about the effectiveness of current educational approaches in preparing students for practical challenges in SD projects. This study investigates the alignment between architecture and construction management students' perceptions of BIM with SD. The research objectives are to (1) identify gaps, (2) assess students' current knowledge, and (3) evaluate teaching methods to enhance education. The study involves students from _ State University (_SU). It compares perceptions across majors and educational experiences to shed light on the influence of students' backgrounds on their understanding of Sustainable Design. The study's main findings reveal that students' experiences significantly impact their comprehension of SD and construction options. Therefore, educators must refine curricula and implement BIM and SD effectively. This research contributes to advancing BIM and SD education, offering valuable perspectives on students' awareness and perceptions within their academic journey. The study will help students apply Sustainable Design in the real world by bridging the gap between theory and practice.

Keywords: Building Information Modeling, BIM, Architecture, Construction Management, Student Learning Outcome, Sustainable Design, Curriculum Development.

Introduction

In the rapidly evolving field of AEC education, economic, social, and environmental factors are driving significant changes in the industry [1]. As a result, integrated practices of BIM and SD have been introduced to enhance student learning outcomes (SLOs) in this sector [2]. However, integrating BIM and SD in higher education programs is often incomplete, as they are taught separately, limiting students' learning potential [3]. This is where the Department of Construction Management at _SU comes in; their program is recognized by the American Council for Construction Education (ACCE) and strives to prepare the workforce with competencies in BIM and SD by adapting college curricula to the evolving industry [4]. While research on BIM standards or guidelines and their application to sustainability is lacking, recent BIM studies have highlighted certain aspects of sustainability, making it an essential trend that educators must effectively implement.

Sustainable design is a crucial aspect that considers the environmental, social, and economic impacts throughout a project's life cycle [5]. This approach aligns with the United Nations'

Sustainable Development Goals, which address vital issues across society, the environment, and the economy [6]. Sustainable construction emphasizes using renewable materials and reducing energy consumption and waste to lessen the industry's environmental impact [7]. By adopting sustainable practices, we can ensure that present and future generations can live comfortably on our planet. It is not just an option but a necessity for the well-being of everyone.

This study evaluates the effectiveness of sustainability preparation through university education by investigating architecture and construction management students' perceptions of BIM and SD. The study focuses on the Department of Construction Management at _SU and aligns with program assessment, improved SLOs, and emerging industry needs. Our mission is to enhance student outcomes and meet the evolving needs of the industry by understanding how students at _SU perceive SD and the use of BIM and developing their skills in both areas to prepare them for future careers in construction. The university teaches BIM with sustainability beyond theory, delving into students' real-world experiences and exploring their aspirations for sustainability post-graduation, observations of sustainability benefits and challenges in the future, and perceptions of sustainable courses.

Background

Integration of BIM and Sustainable Design Education

Integrating BIM and SD education is critical to modern construction and engineering curricula. Integrating these two fields has numerous educational benefits, including improved student competencies in sustainable development, communication, teamwork, problem-solving, and critical thinking.

According to [8], integrating BIM as a pedagogical and technical tool is critical to teaching sustainability in construction education. The study highlights the importance of incorporating BIM software packages, such as Revit Architecture, Revit MEP, and Autodesk Ecotect, to conduct sustainability analyses during building design and construction. This hands-on approach allows students to gain practical BIM experience for sustainable building design and energy analysis. Furthermore, integrating BIM and sustainability education involves assessing students' understanding of sustainable development principles and BIM implementation [9]. The study presents the results of student surveys, demonstrating the positive impact of BIM-based sustainability courses on students' knowledge and perceptions of sustainable development principles. The assessment results indicate improved student competencies related to sustainable development and other essential skills.

In addition to student assessment, [10] emphasizes the need to update and align curriculum content to meet the needs of the industry and incorporate BIM into higher education curricula. Expert input from faculty members and professionals in the construction industry is leveraged to assess the integration of BIM into the curriculum in higher education [10]. This collaborative approach ensures the curriculum aligns with industry requirements and prepares students for sustainable building design and construction challenges. Discovering the integration of BIM and

sustainable design education also involves methodological considerations, such as using green BIM tools, the status of the building industry, and sustainable development literature in advanced courses of construction education programs [9]. The authors highlight the importance of providing students with a quick review of relevant literature and workshops to develop building projects that address social problems and propose sustainable solutions using BIM models.

Moreover, the integration of BIM and Sustainable Design education is positioned to prepare students for the challenges of the 21st century in terms of both design and construction. [11] argue that BIM education and training are essential for equipping a new generation with the skills required to meet the demands of sustainable building design and construction. The integration is viewed as mutually beneficial for students and the construction industry, as it prepares students to be members of the "BIM age." It addresses the paramount significance of attracting qualified and diversified students into civil engineering programs in the context of sustainable civil engineering [11].

Accordingly, several research papers have explored the integration of BIM and Sustainable Design in education. However, gaps in the research include the effectiveness of integrating these topics in education, the role of industry partnerships, and the effectiveness of different teaching methods. Addressing these gaps can contribute to a more comprehensive understanding of how BIM and Sustainable Design can be effectively integrated into architecture and construction education.

Educating methods to enhance the integration of BIM and Sustainable Design

The literature review highlights the significance of pedagogical approaches, incorporating BIM tools into the curriculum, and interactive learning methods in enhancing the integration of BIM and SD education. Students gain hands-on experience, develop critical thinking skills, and acquire a deeper comprehension of SD principles through these instructional approaches. However, there is a need for further research to address the identified gaps and develop standardized guidelines for integrating BIM tools into SD curricula, ultimately preparing future professionals to address sustainability challenges in the AEC industry effectively. Collaborative project-based learning is one approach to enhancing the integration of BIM and SD education. [1] emphasized the benefits of this approach, highlighting the potential of integrating BIM into SD decision-making processes. This approach allows students to work on real-world projects, applying BIM tools to analyze and optimize SD solutions. Additionally, the study by [12] demonstrated the impact of integrating BIM and energy modeling in a case study, indicating that hands-on experience with BIM tools can significantly enhance students' confidence and perceptions about SD and construction.

Another approach is incorporating BIM tools into the SD curriculum. According to [10], a structured curriculum planning framework is essential to effectively integrating BIM and SD education. By incorporating BIM tools into the curriculum, students can gain practical experience using BIM for SD analysis, energy modeling, and lifecycle assessments. This hands-on approach allows students to develop critical thinking skills and apply SD principles using BIM technology. Interactive and simulation-based learning methods have also been explored to

enhance the integration of BIM and SD education. By incorporating interactive BIM software such as Revit Architecture, Revit MEP, and Autodesk Ecotect, students can engage in simulation exercises to conduct “what-if” sustainability analyses during building design and construction scenarios [1]. This approach to learning engages students by showing them how design and construction choices can impact the sustainability of a building, leading to a better understanding of SD principles.

Moreover, [8] focuses on providing students with practical experience using BIM software for sustainable building design and energy analysis, preparing them for challenges in construction. BIM software packages also enable students to gain practical experience conducting sustainability analyses during building design and construction, offering them a deeper understanding of the challenges and opportunities in sustainable building design and construction. Concurrently, [13] provides students with practical experience working with large open-source datasets, helping them develop critical data management and analysis skills for modern construction and engineering. As also suggested by [8], collaborative projects offer opportunities to build communication, teamwork, and problem-solving skills. In addition, working with diverse groups prepares students for modern construction and engineering challenges.

While the reviewed literature provides valuable insights into teaching methods to enhance the integration of BIM and SD education, research gaps still need to be addressed. Initially, there is a need for more empirical studies that evaluate the long-term impact of different pedagogical approaches on students' proficiency in using BIM for SD analysis. Additionally, future research should focus on developing standardized guidelines for integrating BIM tools into SD curricula, ensuring that students receive comprehensive training in leveraging BIM technology for sustainable construction practices.

Investigate students' perceptions of BIM and Sustainable Design

BIM and SD are two critical topics in the architecture and construction management fields. BIM is a digital tool that allows architects, engineers, and construction professionals to create and manage building information throughout the project lifecycle. On the other hand, sustainable design focuses on designing environmentally friendly, energy-efficient, and sustainable buildings. While both topics are essential, aligning architecture and construction management students' perceptions of BIM and SD is necessary to ensure effective teaching and learning.

Several studies have investigated the alignment between architecture and construction management students' perceptions of BIM and SD. One such study is “Perception of Students’ Understanding of BIM with Sustainable Design” by [14]. The study surveyed architecture and construction management students to understand their perceptions of BIM and SD. The results showed that both groups recognized the importance of BIM as a vital tool, exhibited familiarity and competency in using BIM, and acknowledged the significance of SD. However, architecture students may emphasize the practical application of BIM and SD in real-world construction projects. In contrast, construction management students may prioritize using BIM for project coordination and scheduling. Similarly, [10] investigated the impact of BIM integration on SD

education and found that students exposed to BIM-based Sustainable Design education had a better understanding of the concepts and were more likely to apply them in their future careers.

Another study, [1] explored the alignment between architecture and construction management students' perceptions of BIM and SD through collaborative project-based learning. The study found that students from both disciplines recognized the importance of BIM and SD in the construction industry. However, architecture students may approach SD from a design innovation and aesthetic standpoint, while construction management students may perceive SD from a project management and cost-efficiency perspective. In addition, [15] has highlighted that most students in both programs express an interest in pursuing a sustainable education after graduation, with architecture students particularly inclined towards this field, irrespective of their area of study or the distribution of respondents.

A study conducted by [12] examined the perceptions of architecture and construction management students regarding BIM and SD. The results showed that students had a favorable perception of both BIM and SD and believed that integrating BIM could SD education. However, the study also revealed that students lacked the necessary skills and knowledge to use BIM for SD effectively. Another study by [16] examined the use of BIM for effective visualization teaching approaches in construction education. The study concluded that using BIM-based visualization tools could enhance students' comprehension of SD concepts and improve their ability to communicate effectively with other professionals in the industry.

As a result, studies show that both groups recognize the significance of BIM and SD. However, architecture students emphasize practical application, innovation, and aesthetics, while construction management students prioritize project coordination and cost efficiency. Integrating BIM into SD education can enhance students' comprehension and ability to communicate effectively with other professionals in the industry.

Methodology

A recent study by researchers at ___ State University surveyed architecture and construction management students to assess their experiences and perceptions of BIM with SD and the sustainability preparation they received through their university education. The survey was conducted online via Qualtrics software and included multiple-choice, Likert scale, and slider scale questions. The survey aimed to understand how students think about SD and construction and how sustainable education affects their understanding of the subject. The survey results were exported to Excel and analyzed for differences and similarities between the architecture and construction management programs. The survey was designed to examine three key aspects of students' perceptions of BIM and SD: their familiarity with applying BIM, their basic knowledge of SD concepts, and their perception of BIM and SD. The survey questions were divided into three types and developed from literature and other research. The first questionnaire used a Likert scale to investigate respondents' awareness and perceptions of using BIM to achieve sustainable building design. The second type of questionnaire was an expert opinion survey designed to collect preliminary information from construction experts. The third type of questionnaire included open-ended questions to gather feedback from students about the overall

concept of BIM with SD. The survey was delivered, and 110 participants responded, including students from the Architecture and Construction Management departments.

Data Analysis

A research study was conducted at _ State University to analyze students' perceptions of BIM and SD in the architecture and construction management program. The survey was conducted online throughout the semester and included open-ended questions regarding their overall experience. The results indicated that the project course significantly impacted students' understanding of fundamental BIM and SD concepts. The survey had 110 participants, 67 of whom were Architecture students, and 43 were Construction Management students. Most participants were between the ages of 18 and 24.

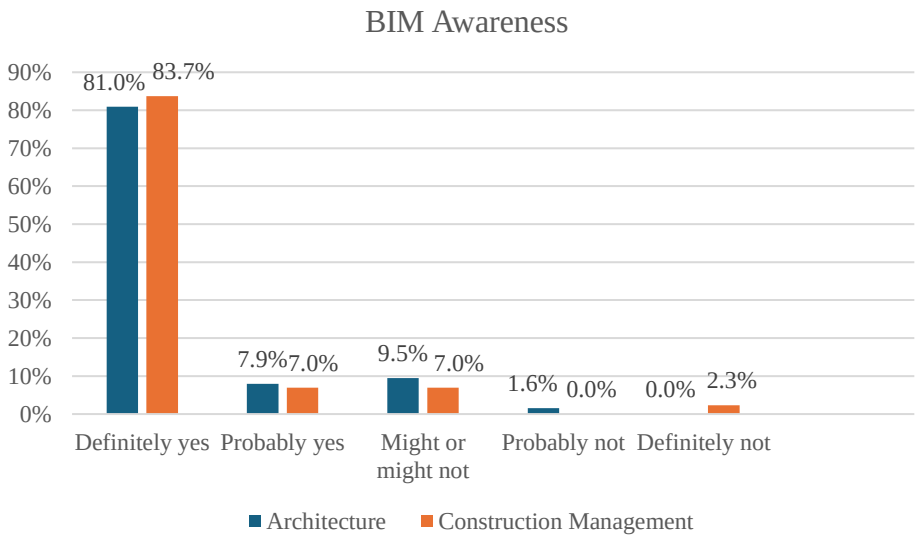

Figure 1: Participants' response to the awareness of BIM

As shown in Figure 1, the study compared the level of BIM awareness between Architecture students and Construction Management students. The results indicated that both disciplines exhibit a strong understanding of Building Information Modeling (BIM) or Virtual Design and Construction (VDC), or Digital design and construction (DDC). Most Architecture students (80.95%) responded with a definite "Definitely Yes" when asked about their BIM awareness, while Construction Management students demonstrated a high awareness level, with 83.72% responding "Definitely Yes." Only a small percentage of students had doubts about their BIM understanding, with Architecture students at 9.52% and Construction Management students at 6.98%. The results concluded that both groups have a high and confident level of BIM awareness, with Architecture students being slightly more certain about their knowledge.

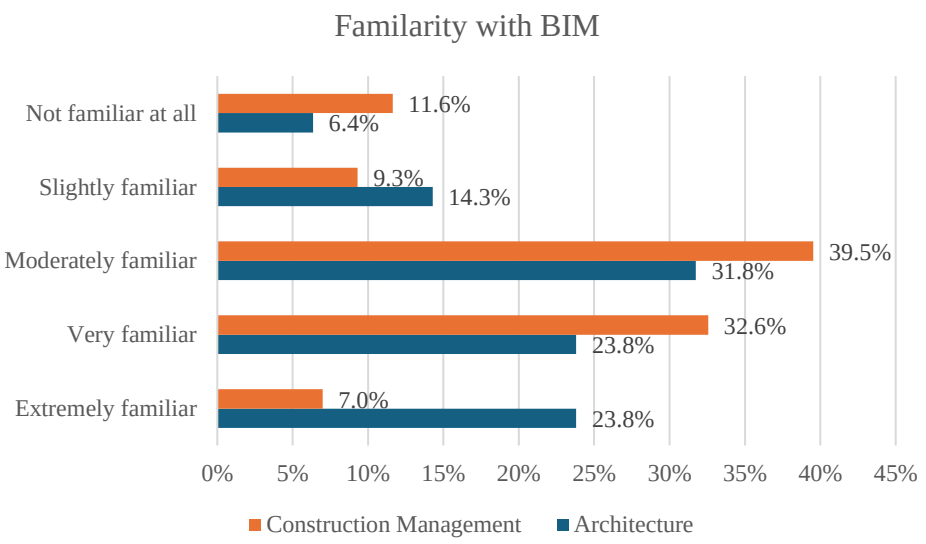

Figure 2: Participants' response on familiarity with BIM

Figure 2 describes a comparison of familiarity with BIM. The results indicate that Architecture students have a higher familiarity level with BIM than Construction Management students, across all familiarity levels. Nearly half of Architecture students reported being "Extremely" or "Very Familiar" with BIM, while only about one-third of Construction Management students reported the same level of familiarity. The remaining students in both groups ranged from "Moderately" to "Not Familiar at All" with BIM.

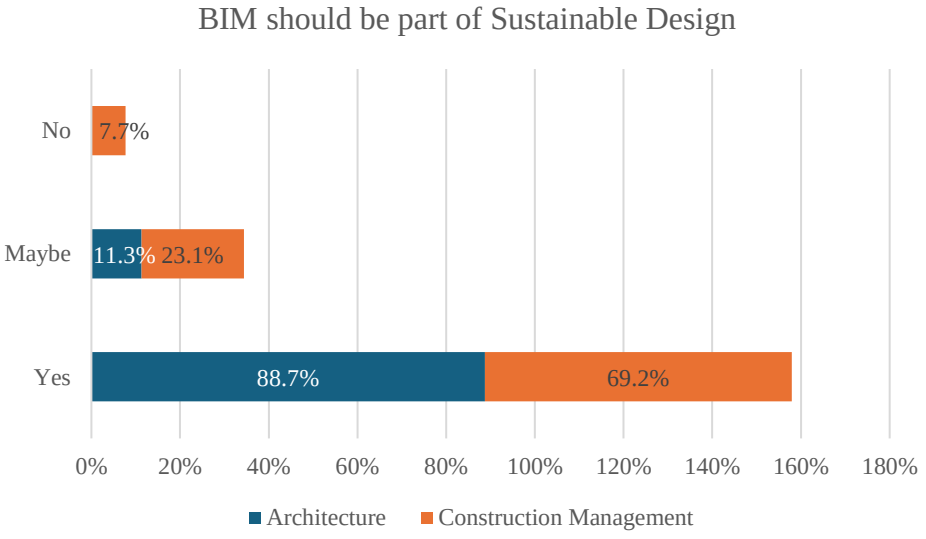

Figure 3: Participants' response on the idea of integration of BIM and Sustainable Design

The results of Figure 3 indicate that there is a difference in opinion between Architecture students and Construction Management students regarding the integration of BIM and SD. Most Architecture students (88.7%) believe that BIM should be included in SD, while only a few of

them (11.3%) are unsure about it. On the other hand, 69.2% of Construction Management students support the idea, but a significant number (23.1%) are uncertain about it and a small group (7.7%) reject the idea. These findings reveal that Architecture students are more enthusiastic and in agreement about integrating BIM with SD than Construction Management students, who have a wider range of opinions on the matter.

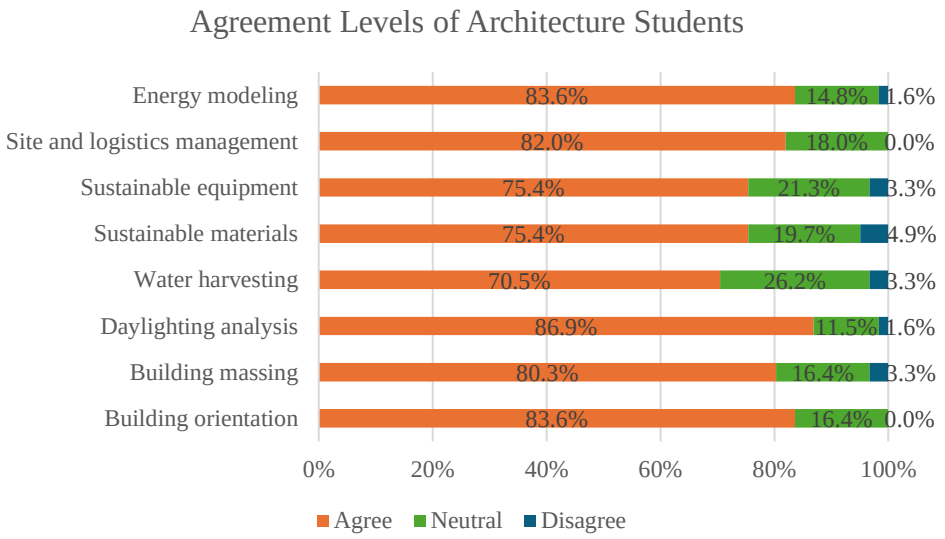

Figure 4: Response to BIM can enhance Sustainable Design aspects (Architecture).

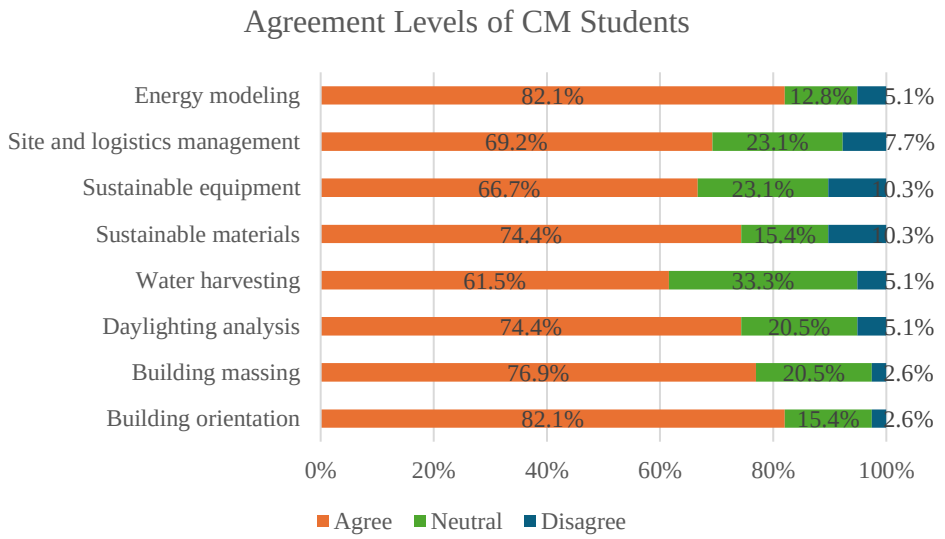

Figure 5: Response on BIM can enhance Sustainable Design aspects (Construction Management).

The results of students' perspectives on the integration of BIM in SD reveal interesting insights. About building orientation, a substantial majority of Architecture (83.6%) and CM (82.1%) students express agreement, with minimal disagreement. Similarly, when considering building

massing, the agreement is prominent among Architecture students (80.3%), while Construction Management students exhibit a slightly lower agreement (76.9%). Regarding daylighting analysis, Architecture students strongly agree at 86.9%, whereas CM students, while still favorable, show a comparatively lower agreement at 74.4%. Water harvesting sees a notable agreement from both groups, with Architecture students at 70.5% and CM at 61.5%. Sustainable materials garner positive responses, with Architecture students at 75.4% agreement and CM students at 74.4%. In sustainable equipment, Architecture students express a 75.4% agreement, while CM students exhibit a slightly lower agreement at 66.7%. Both groups strongly agree on site and logistics management, with Architecture students at 82.0% and CM students at 69.2%. Lastly, energy modeling sees high agreement from both disciplines, with Architecture students at 83.6% and CM students at 82.1%. These findings highlight a generally favorable disposition toward BIM's potential contributions to various aspects of SD, with nuanced variations between Architecture and CM students' perspectives.

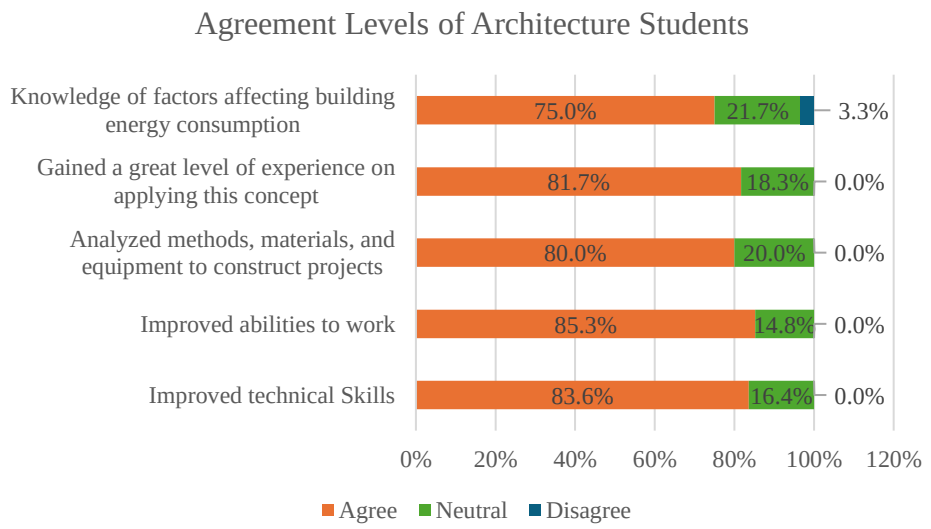

Figure 6: Participants' response on the benefits of understanding BIM in the relation with Sustainable Design (Architecture).

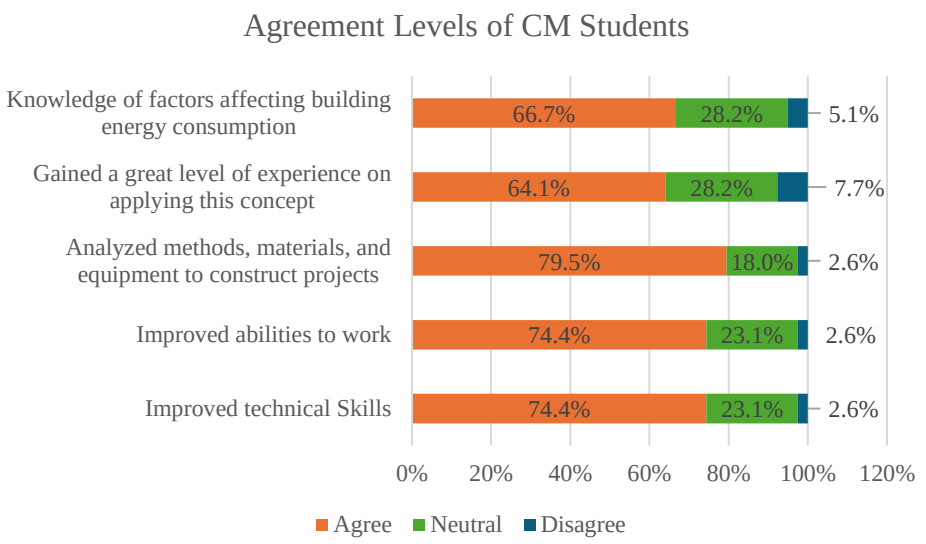

Figure 7: Participants' response on the benefits of understanding BIM in the relation with Sustainable Design (Construction Management).

The research comparing agreement levels between Architecture and CM students regarding the perceived benefits of understanding BIM with SD provides valuable insights. Both groups express high agreement in terms of improved technical skills, with 83.6% of Architecture students and 74.4% of CM students concurring. Similarly, they agree on improved abilities to work, with 85.3% of architecture students and 74.4% of CM students in agreement. Analyzing methods, materials, and equipment to construct projects receives considerable agreement from both disciplines, with 80.0% of Architecture students and 79.5% of CM students. 81.7% of Architecture students acknowledge gaining great experience in applying this concept, whereas CM students exhibit a slightly lower agreement at 64.1%. Knowledge of factors affecting building energy consumption is well-received by both groups, with 75.0% agreement from Architecture students and 66.7% from CM students. These findings underscore the shared appreciation for the perceived benefits of integrating BIM with SD in both Architecture and Construction Management education.

Results and Discussions

The students' viewpoints on the open-answer question provide opinions on improving the program's curriculum and the integration of BIM with SD. Most respondents expressed positive sentiments, believing BIM is crucial to achieving effective and SD. The general tone of comments is positive, with descriptors such as "great," "fun," and "helpful" recurring frequently. Comments indicate that BIM is an efficient tool that enhances the realism and efficiency of design concepts. However, some students acknowledged a potential divide between the technical nature of BIM and the holistic understanding required for SD.

Respondents highlighted the practical benefits of BIM for SD, such as testing SD, creating LEED-certified buildings, and providing quick results with sustainable measures. One respondent aptly captures this sentiment, stating, “BIM definitely has the potential to make SD more realistic.” Suggestions for improvement focused on education and integration, including better educational strategies, hands-on methods, and clearer labeling of sustainable features within BIM. Architecture students believed BIM is crucial for achieving true SD, while CM students focused on the practical aspects of BIM in sustainable construction. One student note, “Using BIM with Sustainable design will help to understand a project better.” Both groups recognized the need for education and seamless integration of BIM into design and construction Table 1 summarizes the nuanced perspectives of architecture and CM students, facilitating a better understanding of their varied perceptions in BIM and SD:

Table 1: Similarities and differences between architecture and construction management students' perceptions of BIM and Sustainable Design

#	**Students’ perspectives**	**Architecture**	**Construction Management**
Similarities	Recognition of BIM's Importance	Recognize BIM as a vital tool for understanding architectural and MEP systems, detecting clashes, and improving project visualization	Recognize BIM as a vital tool for project coordination and scheduling
	Understanding of Sustainable Design	Acknowledge the significance of SD and its integration into the curriculum, indicating a shared awareness of the importance of sustainability in the built environment	Perceive SD from a project management and cost-efficiency perspective
	Competency in BIM	Exhibit familiarity and competency in using BIM, recognizing its value in understanding building systems and its influence on demanding SD in construction practices	Exhibit familiarity and competency in using BIM, recognizing its value in project coordination and scheduling
Differences	Emphasis on Practical Application	May expose a stronger focus on the practical application of BIM and SD in real-world construction projects, given their orientation towards design and visualization	May prioritize the use of BIM for project coordination and scheduling
	Technical Proficiency	May demonstrate a higher level of technical proficiency in BIM tools due to the emphasis on design and visualization in their curriculum	May prioritize the use of BIM for project coordination and scheduling
	Perception of Sustainability	May approach SD from a design innovation and aesthetic standpoint	May perceive SD from a project management and cost-efficiency perspective

*Note: The table summarizes insights from literature reviews and surveys.

As mentioned in the Table, both groups recognize the importance of BIM, but with different emphases. Architecture students use BIM to understand architectural and MEP systems, detect clashes, and improve project visualization. On the other hand, CM students view BIM as essential for project coordination and scheduling. Both groups understand SD, but architecture students emphasize its integration into the curriculum, while construction management students approach it from a project management and cost-efficiency standpoint. Despite these similarities, there are notable differences in the emphasis on practical application, technical proficiency, and perception of sustainability. Architecture students prioritize the practical application of BIM and SD in real-world construction projects, while CM students prioritize it for project coordination and scheduling. Understanding these differences is crucial for educators to tailor their teaching methods and curricula effectively. By recognizing these differences, educators can provide targeted instruction that aligns with students' professional paths, preparing them for the diverse challenges within the architecture and CM professions. Ultimately, the synthesis of BIM and SD perspectives contributes to the holistic development of students, preparing them for the interdisciplinary demands of the evolving built environment curricula. In general, the opinion across both groups was optimistic, believing that BIM is a valuable tool that can contribute to more efficient, sustainable, and visually compelling projects in the future.

Limitations and Recommendations

The study has some limitations as it only focuses on the Department of Construction Management at _SU and may not apply to other institutions. Also, the findings of the study are based solely on students' perceptions regarding BIM, SD and construction and may not reflect the perspectives of industry professionals. Nonetheless, the study's results will benefit educators and industry professionals in promoting sustainable AEC education and practice practices.

Many studies have explored students' knowledge and perception of BIM and SD, but more research is required to examine the effectiveness of integrating these topics in education. One recommendation is to conduct a longitudinal study that follows students from their initial exposure to BIM and SD through graduation and into their careers. Another suggestion is to explore the effectiveness of different teaching methods for integrating BIM and SD, such as traditional lecture-based teaching versus project-based learning. Industry partnerships can also play a crucial role in enhancing students' understanding and application of BIM and SD. By providing real-world experience and exposure to the latest technologies and practices in the construction industry, industry partnerships can help students prepare better for their future careers.

Conclusion

Integrating BIM and Sustainable Design in education is crucial for architecture and construction fields. BIM is a digital tool that allows professionals to create and manage building information throughout the project lifecycle. Sustainable Design focuses on developing environmentally

friendly, energy-efficient, and sustainable buildings. Combining these topics in education can help students develop the skills and knowledge necessary to design and construct sustainable buildings. This research contributes to the body of knowledge by investigating the alignment between architecture and construction management students' perceptions of BIM and SD. Our research suggests that refining curricula and effectively implementing BIM and SD in education will help solve the most significant problems faced by architecture and construction management industries, such as the need for environmentally friendly, energy-efficient, and sustainable buildings. BIM and SD can help revolutionize AEC practices and lead to a more sustainable and efficient industry. Most significantly, the approach proposed in our research advanced the prior works by suggesting a longitudinal study to follow students from initial exposure to BIM and SD through graduation and into their careers. This study benefits professionals and academics by providing a framework for comparative analysis and offering insights into the effectiveness of integrating BIM and SD in education. Although there are some limitations, this study's findings will be valuable to educators and industry professionals in enhancing sustainable practices in AEC education and practice.

References

[1] W. Wu and Y. Luo, "Investigating the Synergies of Sustainability and BIM through Collaborative Project-based Learning," presented at the 2015 ASEE Annual Conference & Exposition, Jun. 2015, p. 26.1043.1-26.1043.13. Accessed: Jan. 30, 2022. [Online]. Available: https://peer.asee.org/investigating-the-synergies-of-sustainability-and-bim-through-collaborative-project-based-learning

[2] W. Wu and Y. (Vivien) Luo, "Pedagogy and assessment of student learning in BIM and sustainable design and construction," *J. Inf. Technol. Constr. ITcon*, vol. 21, no. 15, pp. 218–232, Jul. 2016.

[3] A. Abbas, Z. U. Din, and R. Farooqui, "Integration of BIM in Construction Management Education: An Overview of Pakistani Engineering Universities," *Procedia Eng.*, vol. 145, pp. 151–157, Jan. 2016, doi: 10.1016/j.proeng.2016.04.034.

[4] Y. Luo and W. Wu, "Sustainable Design with BIM Facilitation in Project-based Learning," *Procedia Eng.*, vol. 118, pp. 819–826, 2015, doi: 10.1016/j.proeng.2015.08.519.

[5] A. Ragheb, H. El-Shimy, and G. Ragheb, "Green Architecture: A Concept of Sustainability," *Procedia - Soc. Behav. Sci.*, vol. 216, pp. 778–787, Jan. 2016, doi: 10.1016/j.sbspro.2015.12.075.

[6] M. Roseland and M. Spiliotopoulou, "Converging Urban Agendas: Toward Healthy and Sustainable Communities," *Soc. Sci.*, vol. 5, no. 3, Art. no. 3, Sep. 2016, doi: 10.3390/socsci5030028.

[7] K. I. Vatalis, O. Manoliadis, G. Charalampides, S. Platias, and S. Savvidis, "Sustainability Components Affecting Decisions for Green Building Projects," *Procedia Econ. Finance*, vol. 5, pp. 747–756, Jan. 2013, doi: 10.1016/S2212-5671(13)00087-7.

[8] Z. Shen, W. Jensen, B. Fischer, and T. Wentz, "Using BIM to teach design and construction of sustainable buildings," 2012. doi: 10.18260/1-2--22177.

[9] B. Sanchez, R. Ballinas-Gonzalez, M. X. Rodriguez-Paz, and J. A. Nolazco-Flores, "Usage of Building Information Modeling for Sustainable Development Education," presented at the 2020 ASEE Virtual Annual Conference Content Access, Jun. 2020. Accessed: Jan. 31,

2022. [Online]. Available: https://peer.asee.org/usage-of-building-information-modeling-for-sustainable-development-education
[10] J. Zhang, K. Schmidt, and H. Li, "BIM and Sustainability Education: Incorporating Instructional Needs into Curriculum Planning in CEM Programs Accredited by ACCE," *Sustainability*, vol. 8, no. 6, Art. no. 6, Jun. 2016, doi: 10.3390/su8060525.
[11] S. Atabay, A. Pelin Gurgun, and K. Koc, "Incorporating BIM and Green Building in Engineering Education: Assessment of a School Building for LEED Certification," *Pract. Period. Struct. Des. Constr.*, vol. 25, no. 4, p. 04020040, Nov. 2020, doi: 10.1061/(ASCE)SC.1943-5576.0000528.
[12] A. M. Lewis, R. Valdes-Vasquez, C. Clevenger, and T. Shealy, "BIM Energy Modeling: Case Study of a Teaching Module for Sustainable Design and Construction Courses," *J. Prof. Issues Eng. Educ. Pract.*, vol. 141, no. 2, p. C5014005, Apr. 2015, doi: 10.1061/(ASCE)EI.1943-5541.0000230.
[13] J. Benner and J. J. McArthur, "Data-Driven Design as a Vehicle for BIM and Sustainability Education," *Buildings*, vol. 9, no. 5, Art. no. 5, May 2019, doi: 10.3390/buildings9050103.
[14] T. D. Nguyen and S. Adhikari, *Perception of Students' understanding of BIM with Sustainable Design*. 2022.
[15] S. Adhikari, K. Bedette, and G. Loreto, "Sustainability-Related Issues among Architecture and Construction Students: Analyzing Perception of Sustainable Design and Construction," presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023. Accessed: Jan. 19, 2024. [Online]. Available: https://peer.asee.org/sustainability-related-issues-among-architecture-and-construction-students-analyzing-perception-of-sustainable-design-and-construction
[16] J. J. Kim, "Effectiveness of Green-BIM Teaching Method in Construction Education Curriculum," presented at the 2014 ASEE Annual Conference & Exposition, Jun. 2014, p. 24.459.1-24.459.11. Accessed: Dec. 18, 2023. [Online]. Available: https://peer.asee.org/effectiveness-of-green-bim-teaching-method-in-construction-education-curriculum