Review of Building Information Modeling (BIM) Education in Enhancing Students' Communication Skills

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Abstract

Building Information Modeling (BIM) refers to a highly collaborative process in the construction management of built assets, changing engineering practices and pedagogical strategy from 2D Computer-Aided Design to 3D visualization. BIM has been rapidly adopted in the Architecture, Engineering, Construction, and Operations (AECO) industry. BIM enables industry professionals to create and share comprehensive engineering information, fostering multidisciplinary communications and collaborations. Higher education institutions of AECO disciplines have integrated BIM education into their programs to satisfy the increasing needs of industry for BIM competencies. However, BIM education has not highlighted improving students' communication skills as one of the essential BIM competencies required by the industry. Therefore, there is a need to identify how BIM education can impact students' communication and enhance their communication skills.

The objective of this research is to investigate the current practices of BIM education for improving students' communication skills. This study conducted a comprehensive literature review and a case study in the '*Building Information Modeling (BIM) (CMT 7030)*' course to examine students' in-depth communication experiences. It was found that the visualization and worksharing techniques of BIM enabled students to interact more frequently, improve the quality and efficiency of their communications, and practice communication skills in a professional manner using technical terminology. The findings of this research provide some noteworthy suggestions for educators and instructors to reinforce the effectiveness of BIM education in improving students' communication skills.

Introduction

BIM Adoption in the AECO Industry

BIM is rapidly transforming the AECO industry [1]. In the United States, over 98% of large architecture firms have adopted BIM for modeling and documentation tasks [2]. The overall adoption of BIM in the AECO industry stands at nearly 80% [2]. BIM assists industry professionals in improving efficiency, reducing errors, and enhancing communications and collaborations in the AECO industry [3], [4], [5]. BIM facilitates collaborations among architects, engineers, contractors, and other stakeholders by providing a centralized and accessible platform for project information [6]. BIM is also utilized for the early detection of clashes or conflicts in the design, reducing the likelihood of errors during construction and minimizing the need for costly rework [7]. BIM enables the project stakeholders to better understand the design and make informed decisions throughout the project lifecycle [8].

BIM can be extended beyond the 3D digital representation of a building or infrastructure, allowing stakeholders to collaboratively design, estimate, analyze, simulate, and visualize various aspects of an engineering project [9]. Using 4D BIM, construction teams can integrate construction schedules with 3D design to visualize the construction process, identify potential bottlenecks and optimize the sequence of activities for efficiency [10]. Quantity surveyors can use 5D BIM to estimate costs more accurately by associating cost data with individual components in the model [11]. Facility managers can utilize 6D BIM for ongoing maintenance, easily accessing information about equipment, systems, and maintenance schedules [12]. Professional can use 7D BIM to analyze the environmental impact of different design options, helping to create more sustainable and energy-efficient buildings [13]. The sustainability analysis using BIM is crucial for designing and constructing environmentally friendly structures [14]. The adoption of BIM in the AECO industry will be accelerated since the consistent digitalization of building and infrastructure information is crucial for improving the productivity and efficiency of the AECO industry [15].

BIM Education and Communication Skills

BIM education is widely and popularly integrated in the higher education programs to satisfy the needs of students and the AECO industry [16]. Most BIM courses involve a multifaceted approach that integrates theoretical knowledge, practical skills development, and real-world applications [17]. Students are expected to learn BIM concepts, fundamentals, theoretical knowledge, and existing industry practices through lectures [18]. Also, practical workshops and labs are often combined with BIM courses [19]. Students in BIM education often have hands-on exercises for creating 3D models, clash detection, and construction sequencing using BIM software like Autodesk Revit or Navisworks [20], [21].

BIM competencies are defined as the set of qualifications required for BIM-related jobholders or candidates, enabling them to effectively fulfill their roles and responsibilities of their BIM-related jobs [22]. BIM competencies can include skills, knowledge, educational background, experience, or licenses [22], [23]. Communication skills are one of the BIM competencies that employers expect from their entry-level or newly-hired engineers [24], [25]. One of the major goals in BIM education is to strengthen students' collaborations and communications [26], [27]. The learning outcomes in most BIM courses includes enhanced communication skills and collaborations of students [27], [28], [28], [29], [30]. The BIM techniques for visualization, worksharing, and information exchange are frequently exploited for improving communications and collaborations in the AECO industry [31]. Visualization can enhance the communication between AECO industry stakeholders, and result in clear and shared understanding between the stakeholders [32]. Advanced visualization techniques of BIM can also advance the pedagogical strategy and improve the efficiency of information exchange between students and instructors in higher education of AECO disciplines [18]. BIM enables students to access, exchange, and share comprehensive building information in a single interface [33]. The worksharing technique of BIM provides 24/7 access to a shared model as known as a central model and up-to-date information for students [34], [35]. Collaborative tasks in BIM education using the worksharing technique can foster interactions and communications between students [36].

Research Methods

This study was conducted using two methods: (1) Literature review and (2) Case study. The existing literature and studies have been reviewed through a bibliometric search to identify the current practices of BIM education that focuses on improving students' communication skills. The bibliometric search is based on keywords in either the title, abstract, or keyword lists of literature [16]. The keywords including 'Building Information Modeling (BIM),' 'communication skills' and 'higher education' were used for collecting the initial literature sample. *Google Scholar* and *Scopus* were used as a database for searching literature and references because they offer a considerable number of recent literature compared to other databases [37]. Journal articles and conference proceedings were both included for reviewing the current practices of BIM education across the AECO disciplines. The initial literature sample from the databases was further screened based on the scope of the study. The scope of the literature review focuses on educational studies that investigate the effectiveness of BIM education in enhancing the communication skills of students in the higher education of the AECO disciplines as shown in Figure 1.

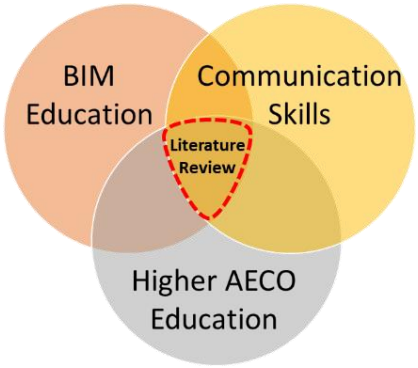

Figure 1. Scope of the Literature Review

These educational studies include but are not limited to teaching activities, pedagogical strategies, curriculum development, and student feedback collection (e.g., student discussions or perceptions of BIM). The type of literature that do not focus on (1) BIM education, (2) communication skills, and (3) higher AECO education was excluded from the literature sample after further screening.

After reviewing the current practices of BIM education for enhancing students' communication skills, a case study was conducted for graduate students enrolled in the '*Building Information Modeling*' course in Engineering Technology of Wayne State University in Fall 2023. The BIM course included lectures, hands-on exercises, and term project. The instructor taught theories, practices, applications, and knowledge of BIM in the construction engineering and management industry during lecture sessions. After every lecture session, students were asked to complete hands-on exercises regarding the lecture contents and submitted their exercises as weekly assignments. Also, students completed, presented, and submitted term project documents, applying the comprehensive BIM techniques and knowledge that they have learned throughout the course.

At the end of the course, in addition to exam questions evaluating the students' BIM competencies and knowledge, students were asked to respond to open-ended survey questions about their communication experiences and skill development throughout the BIM course. The open-ended

responses of students in the BIM course were collected and qualitatively examined to identify the student's experiences and perceptions about how the BIM techniques impacted their communication skills including the quality, contents, and delivery formats of their communications. Based on the literature review and case study, qualitative discussions and implications were provided to understand the challenges of current BIM education in improving students' communication skills and suggest the near-future directions for educators and instructors to address the challenges and enhance the BIM education.

Results

Literature Review Results

More than three thousand documents including journal articles and conference proceedings were searched in the databases. The initial sample of literature was screened and selected based on the scope of the study and selection criteria (i.e., BIM education for enhancing communication skills in the higher education institutions of AECO disciplines). Two types of literature were excluded: (1) Literature focusing on BIM in the higher education institutions of AECO disciplines but not on students' communication skills improvements and (2) Literature focusing on students' communication skills improvements in the higher education institutions of AECO disciplines but not on BIM.

Table 1 summarizes the findings of the current research on BIM education for enhancing students' communication skills in the higher education institutions of AECO disciplines. All studies on BIM education focusing on students' communication skills improvements have utilized problem-based or project-based learning approaches.

Table 1. Studies on BIM education for enhancing students' communication skills

Studies	Program/Degree	Findings
[38]	Built Environment	The problem-based learning of BIM showed a high positive impact on improving undergraduate students' communication skills.
[39]	Multidisciplinary AECO program	Multidisciplinary collaboration in BIM capstone project strengthened students' collaboration and communication skills. The quality of students' communications between different majors was improved.
[30]	Construction Management	Teaching communication skills is crucial for students to learn collaborative information delivery methods using BIM.
[40]	Multidisciplinary AECO program	BIM improved students' communication skills most greatly when it is adopted in multiple courses or programs of construction education.
[19]	Multidisciplinary AECO program	Students reflected that they could better learn communication practices and strategies when using the BIM software with actual project data in the industry.

[41]	Multidisciplinary AECO program	Interdisciplinary BIM-based joint capstone course in highway engineering improved students' collaborations and communication skills with other professionals.
[42]	Multidisciplinary AECO program	Autodesk BIM360 was one of the most popular communication tools for students to share files and collaborate in a BIM learning project.
[43]	Multidisciplinary AECO program	The shared BIM model improved collaborations and communications between students.
[44]	Civil and Geodetic Engineering	BIM advances a communication language to exchange ideas and convey knowledge in engineering education.
[45]	Construction Engineering and Management	Students showed improvements in their communication skills after completing the BIM-based construction projects.
[46]	Multidisciplinary AECO program	Developing communication skills of students should be a core learning outcome of BIM course.
[29]	Architecture Technology	The BIM-enabled virtual projects helped students improve their understanding in built-environment and communication skills.
[47]	Construction Engineering and Management	Students answered that BIM could enhance their communications and social skills through workshop sessions.
[25]	Civil Engineering and Management	Students experienced more frequent communications with students and advisors in a team-based BIM education.
[48]	Building Construction	Students' intra-team communications during BIM education differed across academic levels, showing the least satisfaction of graduate students and the greatest satisfaction of senior students.
[21]	Multidisciplinary AECO program	Student responded that sketching using BIM was useful for communicating their design ideas and concepts.
[26]	Multidisciplinary AECO program	UK undergraduate students commented a need for more flexible communication techniques in the BIM or other design education.
[31]	Construction Information Systems	Both educators and industry professionals responded to the Delphi study that BIM course in higher education should teach communication skills and provide collaboration opportunities with industry.

Students' Perceptions of BIM Impacts on Communication

Students shared their experiences and perceptions about how the quality, contents, and delivery formats of their communications were improved by applying the BIM techniques and knowledge for their assignments, project presentations, and project reports. Students' communication experiences were highlighted by two major techniques of BIM: visualization and worksharing.

Table 2 summarizes the student's answers to how BIM could enhance their communication skills such as the quality, contents, delivery formats, and efficiency of communications.

Table 2. Students' experiences in improving communication skills during the BIM course

Technique	Comments
Visualization	• *"BIM provides a 3D visual representation of the entire project, enabling all the stakeholders to have a shared design and construction details."* • *"I used BIM for illustrating a complete project design."* • *"I could have a clear and complete visual image of the building design using BIM."* • *"BIM allowed me to create 4D (time) and 5D (cost) simulations and visualize the construction process."* • *"BIM made it easier for our project team to discuss the project details and information."* • *"We could easily simulate different situations and visualize project scenarios using 3D BIM."* • *"I created construction documents so easily based on my 3D design. BIM made it easier to visualize not only design but also documents."*
Worksharing	• *"BIM enabled me to share information with other students and reduce the risk of miscommunications or misunderstanding."* • *"I could include all construction phases and components in one single shared BIM interface."* • *"I completed my cost estimation task for all construction materials and components using BIM without missing any changes or overlooking mistakes."* • *"I centralized all the project data using BIM."* • *"BIM greatly improved time and efforts required for project communications between other team members."* • *"BIM serves as a comprehensive database that includes all project-related information and data."* • *"BIM was a shared language for me to understand complicated materials."* • *"BIM provided a unified approach to our construction project management."* • *"We could speed up our decision-making process on the BIM interface."* • *"BIM provided our project team with a more open, creative, and shared workplace."* • *"I could successfully track the historical changes of building designs and information using BIM."* • *"Our project team members could have easy access to the most up-to-date information."*

Discussions and Implications

Challenges in BIM Education for Enhancing Students' Communication Skills

Current BIM education faces a few challenges in developing and enhancing students' communication skills [45]. First, current BIM programs in higher education have a limited focus on soft skills including communications, collaborations, and interpersonal skills [21]. Students reported that current BIM courses focus on technical software skills rather than interpersonal skills [21]. Most BIM education programs lack communication training for students to convey their ideas and findings in technical terminology and professional manner using the BIM workflows [26]. Moreover, the current industry practices and communication methods are not well-reflected in current BIM education [21]. Students often struggle with understanding the technical communications in real-world project situations due to inadequate exposures to industry practices [19].

Suggestions for Enhancing Students' Communication Skills in BIM Education

Several suggestions are provided for addressing the current challenges in BIM education and improving the effectiveness of BIM education for enhancing students' communication skills. First, teaching communication skills can be incorporated in BIM education [26]. For example, additional training, workshops, or exercises for teaching and developing communication skills can be integrated with the technical BIM coursework [26], [47]. This coursework or training can involve creating documentation, presenting findings, and using BIM models as communication tools [26]. Students are expected to learn technical communication skills for conveying design intent and contents, exchanging project ideas, and collaborating with team members [25].

Also, interdisciplinary collaboration in BIM education can increase opportunities for student to communicate with students from different backgrounds [40]. Joint projects with students from different disciplines such as architecture, civil engineering, engineering technology, and project management can reflect the multidisciplinary nature of construction projects and assist students to communicate in cross-functional interdisciplinary project teams [39]. For example, students from various disciplines can collaborate and communicate to accomplish a successful highway engineering project management as a shared goal [41].

Furthermore, collaborative initiatives with BIM specialists and industry professionals enable students to learn and practice the technical communications using actual industry practices [19]. For example, inviting BIM specialists as a guest lecturer or external evaluator for students' presentations can assist students to learn the knowledge and skills of technical communications in real-world scenarios [25]. Industry collaborations in BIM education can assist students to bridge the gap between academic learning and industry employers' expectations of communication skills [23], [31].

Conclusions

The current study reviewed existing practices of BIM education for improving students' communication skills as one of BIM competencies. Also, this study conducted a case study and discovered the students' communication experiences on how BIM education affected the quality,

contents, delivery formats, and efficiency of their communications. Students answered that visualization and worksharing features were useful for improving their communications and collaborations during hands-on exercises and term project. For example, students responded that they could reduce the risk of miscommunications or misunderstanding using the worksharing feature of BIM during online communications for completing a term project as a group. The findings of this study are expected to assist educators and instructors in better understanding the current challenges in BIM education and improving the BIM education for enhancing students' communication skills.

Limitations/Future Work

Due to a small sample size of students enrolled in the course, the study only qualitatively examined students' in-depth experiences on how the BIM course affected their communication skills including the quality, contents, delivery formats, and efficiency of communications. Additional quantitative analysis would be recommended in future research to add insights in BIM education for enhancing students' communication skills. Moreover, the findings of the study are based on a student sample from Engineering Technology Division at Wayne State University. It would be interesting to further validate the effectiveness of BIM education for improving students' communication skills in other engineering disciplines, programs, or institutions.

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