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Implementing Building Information Modeling in Architectural, Engineering and Construction Education: A Systematic Literature Review

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Abstract

Architecture, engineering, and construction students must master building information modeling to meet the growing demand for building information modeling specialists in the construction industry. This systematic literature review investigates the current status of building information modeling technology as a learning tool in architecture, engineering, and construction education. The data used four scientific databases, including Scopus, Science Direct, Emerald, Taylor, and Francis Online, published in 2013-2022. The results of this study indicate that this study provides two questions about the process and barriers to implementing building information modeling from 27 articles that meet the inclusion criteria and research topics. Several studies have been identified related to the implementation of building information modeling in architecture, engineering, and construction education, including course development, curriculum development, application of learning methods to integrate building information modeling, learning media, and learning modules. The collected articles are dominated by quantitative research with a focus on civil engineering, architecture, engineering, and construction. Advanced technology and various supporting tools for building information modeling, curriculum design, industry-academia partnerships, student motivation and interest, instructor guidance, and learning resources are very important in determining the results of building information modeling implementation. The results of this study can be used to consider the integration of building information modeling technology in the planning of architectural, engineering, and construction education curricula and learning design.

Keywords: Building, Education, Engineering, Information, Learning Support Tools, Modeling.

Introduction

In the last decade, Building Information Modelling (BIM) has upended Architectural, Engineering, and Construction (AEC) industrial work processes in building and infrastructure development projects (1). BIM is a process resulting from the recent expansion of knowledge. The AEC industry uses it to reduce errors and maximize resource utilization (2). BIM can also be utilized as an effective didactic strategy to improve e-learning outcomes (3). In the construction industry, BIM tools and processes are being adapted and used more extensively (4). BIM has become the paradigm for improving project delivery practices (5). BIM can store, organize, and exchange data from one party to another (6). Real-time data, including environmental and localization data, can now be integrated with BIM to aid construction operations and management. Consequently, BIM proficiency must be developed. BIM as a learning tool can alter the traditional learning process by incorporating BIM into multiple aspects of the lesson (7). As a learning environment, BIM also offers a collaborative platform for communication, BIM workflow processes, etc. BIM has also been shown to enhance the outcomes of building design and construction courses (2). The construction industry plays a crucial role in transferring the accomplishment of construction practices to BIM-based technology (8). Therefore, education providers are urged to develop BIM courses to instil BIM proficiency through instruction (9). The needs for experts in the BIM field continue to increase (9). According to his research, one way to contribute to the industrial world is to develop BIM-related university courses under the desired

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outcomes. It is necessary to teach BIM competencies through an appropriate educational strategy to produce human resources who are experts in mastering BIM technology. Based on this statement, it is clear that integrating BIM into learning or courses is one way to impart BIM technology skills. BIM implementation best practices are required as a reference for other education practitioners on how to implement BIM when learning the scope of Building Engineering. However, best practices for BIM education must still be established (4). In fact, with the continuous development of BIM, opportunities for educational purposes will also increase (3). Similar research has been conducted by several previous researchers. The opportunities and barriers of BIM implementation in construction companies in Kazakhstan through a survey (10). They suggest implementing BIM in other countries. Other research identifies barriers to implementing and developing BIM and the impacts through a literature review (11). Another paper reveals BIM in Malaysia with results highlighting the advantages of BIM in the construction of a company (12). Therefore, they suggest promoting a thorough understanding of BIM and preparing BIM practice standards and guidelines in Education, such as in learning. Furthermore, the survey results show that Malaysia has not been maximized in implementing BIM from public and private sectors with various limitations such as lack of awareness, cost, slow adaptation, and the unavailability of clear guidelines (8). Previous studies have revealed how difficult it is for teachers to master pedagogical competence, especially in implementing BIM in schools. In fact, teacher pedagogical competence is very much needed, especially to understand students, design and implement learning, develop students, disseminate student learning outcomes, and actualize the potential of students. Although it is known that there are problems, previous studies have not explained the process of solving these problems. They only describe the actual conditions in the field without solving the problems. In addition, other studies have often highlighted the implementation of BIM in schools but ignored the obstacles experienced by teachers. Such research has little influence on BIM implementers because it ignores teacher obstacles. Previous literature studies also still ignore the process experienced by users (students). Many studies focus on the implementation of BIM in companies compared to schools. This is in contrast to the needs in the field where schools are also places for BIM development. Some research has similarities with this research in terms of objects, the form of BIM implementation, and the use of research methods. Although there are similarities, this research still has differences in the form of research areas focused on Indonesia and associated with the intervention of building engineering education students. In this study, the focus is not only on intervention but also on the methods, the disciplines, the implementation of the process, and the factors influencing the achievement of BIM implementation. This study attempts to describe the process of implementing BIM in the field of architecture, engineering, and construction education at the university level. Obstacles in the process experienced by students are also reviewed through the process of analysing relevant literature reviews. This is an effort to answer the competence of lecturers in implementing BIM as well as solutions to problems experienced by students during learning. Accordingly, this research provides two basic questions for this literature review, namely:

Q1: How is BIM technology implemented in AEC education learning?

Q2: How is teacher readiness to implement BIM education?

Q3: How are students' perceptions of BIM education issues?

Q4: How does BIM education affect their career opportunities in the AEC industry?

Q5: What are the influencing factors for the success of BIM implementation in building engineering education?

Methodology

Literature Selection Process

This study employs a Systematic Literature Review (SLR) methodology, which identifies, evaluates, and provides answers to research questions based on all available research evidence (13). SLR is a literature review method that identifies, assesses, and interprets all findings on a research topic, to answer research questions (14). The SLR is conducted systematically by

following stages and protocols approving the literature review process to avoid bias and subjective understanding from the researcher.

SLR is well-established in medical research and growth in software engineering (15,16). This is the rationale behind the researcher's SLR-based literature review on the use of BIM for learning in building engineering. The SLR research consisted of five steps: formulating the questions, identifying relevant articles, evaluating the quality of the study, summarizing the evidence, and interpreting the results (17).

Before beginning review work, questions should be formulated unambiguously and organized manner. The questions are framed in terms of the research objectives. After identifying research questions, the next step is identifying relevant articles that answer those questions. The reasons for including and excluding studies should be noted as a criterion for obtaining relevant articles. Following the selection of the articles, a thorough evaluation is conducted on each one to exclude various types of evidence (18). To facilitate the synthesis process, the evidence found in the article to support the answer to the research question is then summarized. The discovered data is then presented for interpretation as the research conclusion (17,18).

Data Collection Instruments

The data collection stages were carried out systematically referring to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines. Previous research data were taken from the Scopus, Science direct, and Emerald, Taylor, and Francis Online databases. The use of this data is because Scopus, Science direct, Emerald, Taylor, and Francis Online are large databases consisting of reputable scientific articles. Scientific articles included in the database are certain to have high credibility. The articles have been reviewed by expert reviewers according to the field with the level of strictness of article acceptance in each database. The keywords used are taken based on the needs and objectives of the research. There is a special theme used in this study, namely the information development model in the field of machine education. From this theme, the keywords for this study include "building information modelling" AND "civil engineering education" OR "building engineering education" OR "architecture engineering education" OR "construction engineering education". Each database is used as a tool to collect articles according to keywords. The tool used is Harzing's Publish or Perish (PoP) software application. A total of 96 articles were found in the literature review process. The articles were then reanalysed by considering the inclusion criteria. This study's inclusion criteria are as follows: (a) This study considers the use of BIM technology in the learning implementation process; (b) articles used beginning in 2013; (c) a research background in civil engineering education, architecture, and Construction (AEC); and (d) English-language publication. After analyzing the articles, the remaining 27 articles are data sources for this research.

Results

Framing the Question

This step aims to formulate precise questions to obtain information regarding implementing BIM technology in engineering education, architecture, and construction learning. These research questions serve as the basis for this literature review:

Q1: How is BIM used to support the educational process in architecture, engineering, and construction?

Q2: What are the barriers to learning associated with implementing BIM to support the learning process of architecture, engineering, and construction education activities?

Table 1 displays the motivations underlying the emergence of the research questions discussed in this study.

Table 1: Research Questions and Motivations in this Literature Review

Code	Research Question	Motivation
Q1	How is BIM technology implemented in AEC education learning?	It identified BIM technology used to support AEC education's learning process.
Q2	How is teacher readiness to implement BIM education?	It identified teacher readiness to implement BIM education.

Q3	How are students' perceptions of BIM education issues?	It identified students' perceptions of BIM education issues.
Q4	How does BIM education affect their career opportunities in the AEC industry?	It identified the effects/impacts of BIM educators on students' career opportunities in the AEC industry.
Q5	What are the influencing factors for the success of BIM implementation in building engineering education?	It identified factors for the success of BIM implementation in building engineering education.

Identifying Relevant Articles

Four scientific databases, Scopus, Science direct, Emerald, Taylor and Francis Online, were searched for articles. Multiple Search strategies were used to locate articles that met the research objectives. The initial step is to identify relevant studies. The second step is to select relevant articles published in 2013 and later. Using the Title-Abs-Key keywords ("building information modelling" AND ("civil engineering education" OR "building engineering education" OR "architecture engineering education" OR "construction engineering education")), the third step is to determine the keywords used to search for articles. Four database searches yielded a total of 96 articles. Several inclusion criteria were applied when screening the obtained articles to maintain the review's focus on the research topic. Articles are excluded if at least one of the following criteria is not met: (a) Studies do not incorporate BIM into the learning process, (b) the articles are not based on empirical research, and (c) the articles are book reviews. After excluding articles by title and abstract, this SLR contains the remaining 27 articles. Figure 1 describes the literature search process.

Assessing Articles' Quality

The articles published in this study demonstrate the efforts of educational researchers to implement BIM technology into construction engineering-related learning. Learning conducted by researchers must include the specifics of the learning process, such as subjects, learning models employed, learning objectives, and given projects. The results of research on the effect of BIM on learning in the context of building engineering, which pertinent theories must support, can also be used to evaluate the quality of research. The assessment of article quality is also based on several things, namely: (i) articles are published from trusted databases (Scopus, Science Direct, Emerald, Taylor and Francis; (ii) articles have been identified manually or through automatic machines to organize articles that are relevant to the research topic; (iii) articles are empirical articles or not literature articles; and (iv) articles have gone through a strict evaluation process in the peer review process of reputable international journals.

Summarizing the Evidence

This step describes each article section, including the research objectives, context, participants, methods, obstacles, and suggestions. The resulting data can be used to answer research questions. The collected articles employed various research methodologies. Figure 2 depicts the proportion of methods utilized by the researcher.

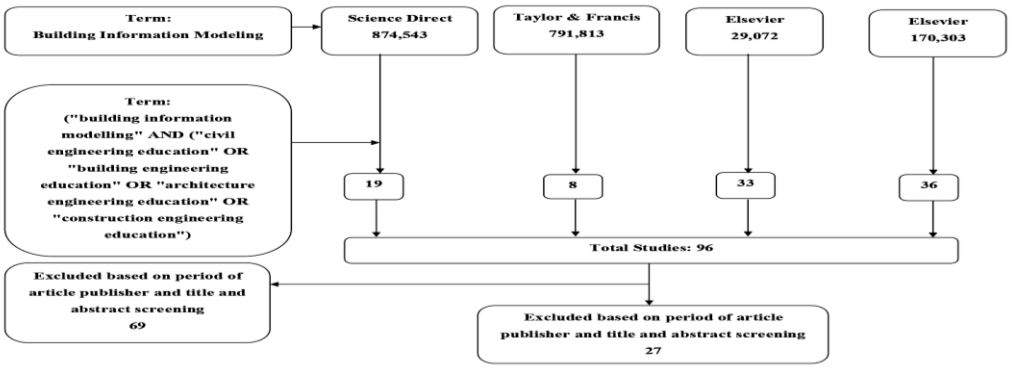

Figure 1: The Process of Finding Literature

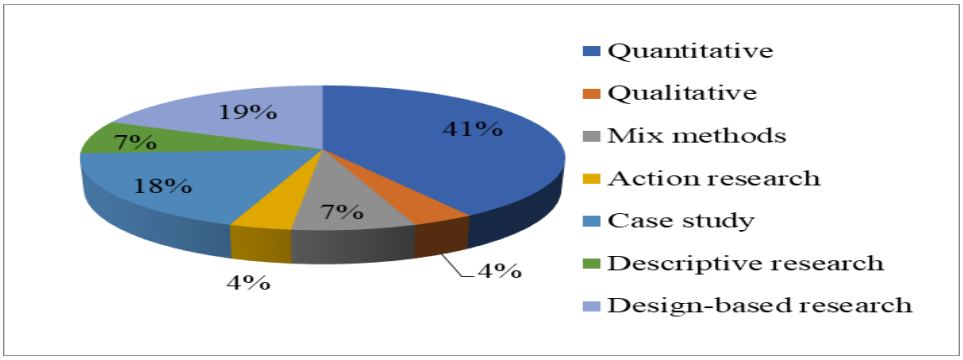

Figure 2: Method of the Studies

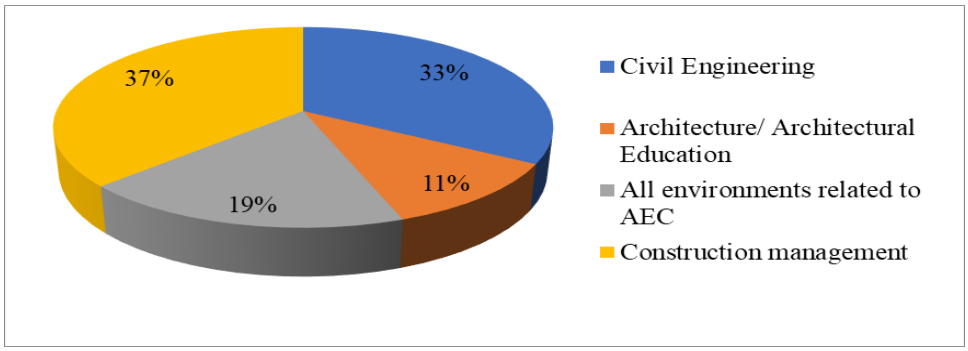

Figure 3: The Distribution of BIM Implementation Studies

The majority of research methods, or 41%, are quantitative, as depicted in the preceding image. Implementing BIM in the building engineering education field also employs descriptive research, design-based research, action research, qualitative methods, mixed methods, and case study. Besides the methods, this research also captures the distribution of BIM implementation. The full presentation is in Figure 3. The distribution of BIM implementation studies is depicted in Figure 3. The majority of studies (38%) chose construction as a case study for BIM implementation. Other documented studies were conducted in Civil Engineering (35%), Architecture (10%), and all AEC-related environments (17%). This study also identifies a number of factors that contribute to the successful implementation of BIM technology in building engineering education. Furthermore, data about the factors affecting the achievement of BIM implementation are presented in Figure 4.

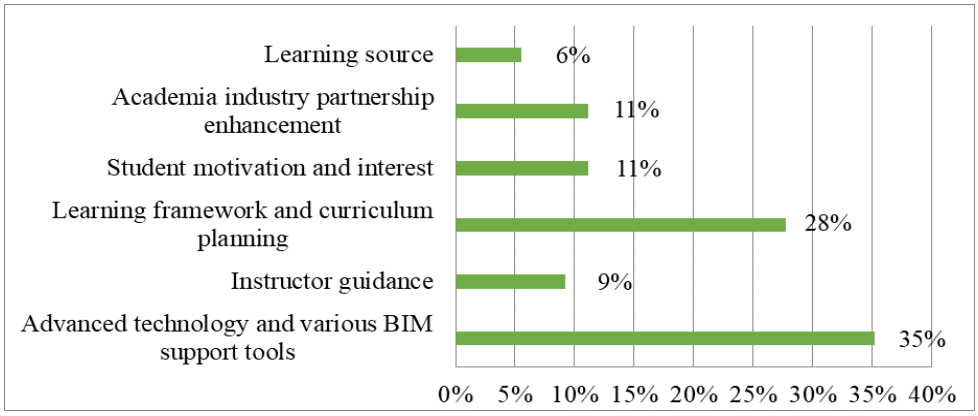

Figure 4: Influential Factors for the Success of BIM Implementation in Building Engineering Education

Several aspects identified as affecting the application of BIM in AEC education were discovered in this study. The aspect of 'advanced technology and various BIM support tools' is the most important factor in determining the outcome of BIM implementation, followed by the learning framework and curriculum planning. Figure 4 describes all factors that influence BIM implementation in building engineering education. Although advanced technology and

various BIM support tools dominate, other aspects remain a significant influence in the implementation of BIM technology. Based on the findings on methods, distribution of BIM implementation and factors influencing the success of BIM implementation, there are new things that are progress in the development of BIM history in education. BIM education is now not only carried out by tertiary institutions, but has also penetrated the school level. Furthermore, previous studies have shown that the methods used by previous researchers are quite diverse. Currently, development research that focuses on BIM has been widely carried out by researchers. Researches with types that are quite avoided such as development research and mixed methods have also increasingly emerged on the surface. Researchers today do not close themselves off from making changes and leaving behind old processes that often-become polemics for the lives of researchers. The presence of development research and mixed research is a new face in the world of research that focuses on BIM education. In addition, the focus of research that was predicted by previous researchers was also not absolute on engineering and building research alone, but also expanded to management research even though the direction was construction management. These two things are progress in the development of BIM history that has been going on so far and are important as a concern for future researchers.

Interpreting the Findings

How is BIM Technology Implemented in AEC Education Learning?

Based on previous stages, it is known that the majority of research on BIM implementation in building engineering education is conducted in construction management, followed by civil engineering, AEC in general, and architecture. Innovative and effective forms of BIM integration in learning are also being sought. Several studies on BIM in the field of building engineering education, such as course development, curriculum development, application of learning methods to integrate BIM, development of learning media, development of learning modules, and so on, have been identified based on the reviewed articles.

The implementation of BIM education has been adjusted to the design of the college curriculum. This design also serves as a guideline for students to be actively involved in learning. In general, the technological infrastructure in schools/colleges is also starting to be adequate so that it can be used as a learning tool or media. Thus, the findings of this study can be used as material for creating a curriculum that considers several things, such as the use of sophisticated technology and various supporting devices for building information modeling, curriculum design, industry-academia partnerships, student motivation and interest, instructor guidance, and learning resources. The integration of building information modeling technology in the planning of architectural, engineering, and construction education curriculum and learning design needs to be a special consideration in the preparation of curriculum documents.

How is Teacher Readiness to Implement BIM Education?

This literature research also prepares data on educators' preparedness to teach BIM. Previous research stated that the level of teacher preparedness for implementing BIM learning has reached the ready category. In line with that, other studies also concluded that the level of preparedness of BIM expertise teachers is categorized as quite prepared. On the other hand, there is a study that concludes that most teachers in one school are still not prepared to implement BIM learning for students majoring in Building Drawing Engineering. This is indicated by the data that: (a) as many as 51.56% of teachers do not understand the principles and implementation of BIM learning; (b) although all teachers have formulated learning activities in the preliminary, core, and closing activities, the realization of these activities is still not in accordance with the provisions, and (c) as many as 61.56% of teachers have not implemented Information and Communication Technology (ICT) in their learning activities. The unpreparedness of teachers in teaching BIM technology is also caused by teachers using conventional models too often. Learning tends to be one-way and passive. There is an assumption by teachers that BIM technology is quite difficult, so they need thorough preparation. The teaching process does not only involve the cognitive side of students, but the psychomotor domain is also dominant in the implementation of learning.

How are Students' Perceptions of BIM Education Issues?

In addition, BIM technology has been implemented in AEC learning. The BIM technology process has received responses from students. BIM learning for students as preparation for facing the world of work that follows technological developments. Unfortunately, there are still some students who do not know and apply the BIM system in carrying out their lecture assignments. Previous research shows that there has not been much progress in the use of BIM in Indonesia due to the limited number of experts in Indonesia who are competent in implementing BIM. There are several problems/obstacles to the implementation of BIM, namely: (i) limited BIM experts; (ii) low knowledge of BIM and its benefits; and (iii) resistance to change. Other studies show that construction companies in developing countries still view BIM as a risky investigation because its business value is not yet clear. From these studies it is also understood that the understanding of BIM in developing countries has not been implemented comprehensively. There are challenges that need to be faced and resolved in the use of BIM technology, including: (i) The need for appropriate education and training to prepare workers in the construction industry to be able to master the use of BIM; (ii) The need for good interoperability so that data can be shared smoothly between various platforms; and (iii) Difficulty in adopting BIM comprehensively across all sectors of the construction industry, especially for small projects and less trained project owners. These challenges are complemented by the need for user knowledge and awareness. This is because the implementation of BIM requires special skills in the use of BIM software and a deep understanding of its methodology.

How Does BIM Education Affect Their Career Opportunities in The AEC Industry?

Currently, many construction industries are looking for human resources to understand and comprehend BIM. In the industrial world, BIM education is very useful for students so that students can pursue careers in the AEC industry. The scope of BIM is very supportive in the preparation of project designs, building structure calculations, to other important information that is well coordinated. BIM is a new program to facilitate work in the AEC field. Another significant opportunity in BIM technology is the development of new innovations, such as integration with artificial intelligence, virtual reality, or sensor technology.

These opportunities are certainly in line with the needs of universities, especially for vocational education students. The effectiveness of project performance and activities in BIM is an added value to the success of construction projects so that career opportunities in this field are very good. According to previous research, the performance of AEC education graduates became more optimal after being taught BIM at school level with fulfilled data, technology, and human literacy competencies. According to other research, BIM technology education offers important advantages, including: (i) BIM enables more effective collaboration between construction project stakeholders; (ii) BIM provides better visualization capabilities, allowing professionals to realistically visualize and analyze projects before their physical implementation; (iii) BIM can optimize planning, reduce overlap, and accelerate the construction process; and (iv) BIM can facilitate easy access to updated building data and support smarter maintenance decisions. Proper and accurate BIM management can provide benefits through a variety of applications for construction monitoring and management, health and safety management, logistics and construction management, and facility management.

What are the Influencing Factors for the Success of BIM Implementation in Building Engineering Education?

Various BIM implementations in building engineering education that previous researchers have carried out are expected to increase the BIM technology's capacity to produce AEC industry-required human resources. Several aspects were identified as factors that influence the implementation of BIM in building engineering education based on the findings of the review article. The most influential factor in implementing BIM in building engineering education is the development of advanced technology and the proliferation of BIM support tools.

This study's literature review reveals how educational actors' efforts to implement BIM in

building engineering education produce the human resources required by the AEC industry. Education service providers in the construction industry must continue monitoring BIM technology's evolution to enhance and modernize the current curriculum, even though implementing BIM technology presents numerous obstacles. As a means of gauging the extent to which students have mastered skills related to the integration of BIM technology, it is necessary to continue exploring a variety of instructional approaches and assessment instruments.

Building Information Modelling (BIM) technology offers many advantages and interesting opportunities for the construction industry, but also has many challenges in adopting it. A good strategy is needed from each party to increase the adoption rate of Building Information Modelling (BIM) to overcome this. One of them is by making planning, standards, and regulations. Material and non-material support is also very important for the motivation of adopting Building Information Modelling (BIM).

Discussion

Framing the Question

The results of this literature review are based on the curiosity to identify BIM technology in supporting AEC learning and the constraints to support the AEC learning process for students. This stage is crucial to deepen the identified focus. The expert states that the identification of questions is the first stage in SLR research (19). From the two questions, it reveals some gaps from the results and becomes a recommendation for other researchers when assessing the research quality. The more aspects that are examined, the more problems will be significantly addressed (14). This step is also in line with the stages conducted by previous researchers about three steps of literature review, namely defining research questions (20). The question determines the characteristics of the prime study and relevant sampling. Questioning becomes a major decision as a follow-up to the next decision (21). Detailing the SLR research question helps advance the research coherently and efficiently (22). Snyder (23) suggests framing the SLR research question.

Identifying Relevant Articles

The findings show that the literature search process is obtained from trusted databases. The number obtained from the literature search is reviewed by examining the same source or duplicate articles from various sources (24). Thus, we employ trusted sources from Scopus for the literature search. Conference papers are avoided since they are incomplete and lousy (25). On the other hand, another research rejects the assumption (26). They mention that the selection of reputable journals is not justified as an excuse to investigate the entire relevant literature. Journal selection does not advocate restriction to specific journals. Other papers use a quality list of specific journals to limit sources (27,28) However, they recommend that authors carefully examine the topic under review.

In the literature search process, search terms are also derived from exclusion criteria and theoretical frameworks (29). In general, two approaches regarding keywords are observed. First, some guidelines suggest to find synonyms of key terms (27). Second, a single keyword is suitable when searching the literature (30). Other search criteria are date of publication, type of article, methods, and keywords covering the domain about the specified search (27,30).

Assessing Articles' Quality

The results of the analysis contain information about Education researchers' efforts to implement BIM technology in learning. The efforts include subjects, models, learning objectives, and projects. Other research results also cover the impact of BIM in learning. Some of the results are widely recognized so that the articles meet high quality. The accuracy of the predetermined criteria (inclusion and exclusion criteria) determines the quality of the articles. It proves from the title, abstract, and keywords of the article (27). On the other hand, the relevance of publications on theories evaluated critically so that the analysis results are not biased (29).

Summarizing the Evidence

The research findings as illustrated in Figure 2 show that qualitative research dominates over other types of research. The number of qualitative studies is based on the advantages of qualitative research. Qualitative research presents more comprehensive results than other methods,

especially for those interested at a phenomenon (31). The method is appropriate since the implementation leads to processes that occur in the field. Thus, the use of qualitative methods is relevant. In addition, some literature has used multidisciplinary. In accordance with the research focus, BIM is practically to the construction field. Thus, it is not surprising that the results dominate from other disciplines. The civil engineering is still related to the BIM implementation. It is highly applied in building modelling, especially for students of building engineering education. Other research also highlights the fields of architecture, engineering, and construction industry as a review of BIM research topics (32). Meanwhile, other sciences still have relevance to the topic of BIM. It allows academics and construction professionals such as architects and contractors to share information in real time, minimize errors and discrepancies, and improve project efficiency. The design of the BIM integration model in architectural education is conducted by previous researchers (33). The application of models to school architecture is still limited to the initial process of implementing BIM, so there is a need to expand the model as a basis for assessment, readiness, development of road maps, and wider exchange of educational terminology.

Furthermore, advanced technology and various BIM support tools are more dominant than other aspects. Meanwhile, previous research actually mentions the driving factors of BIM implementation including trust, respect, commitment, early involvement, and knowledge of BIM (34). BIM have advantages especially in productivity, time, cost, clashes, and communication. Up to the present, these benefits tend to particular interest for the architects. The results of another study reveals that the BIM implementation in Malaysia refers to non-technical factors, such as management, curriculum, partnership, leadership, and coordination rather than technical factors such as software and hardware (35). The findings from the previous researcher are incompatible from the findings obtained from other literature. However, the mentioned factors have intersections with the advanced technology and BIM support tools are component of Engineering. While other factors, such as learning resources, industry partnership achievements, student motivation and interest, learning curriculum, and instructions are non-technical factors. The results regarding the curriculum as the second influential factor provide several reasons. The curriculum is a basic guideline for educators in conducting learning in schools or universities. The curriculum is the key to education so that all implementers have obligation to master it.

Interpreting the Findings

Curriculum development is one form of BIM implementation in building engineering continuing education. Priorities for successful curriculum development in Civil, Engineering, and Management using a quality function deployment guideline to address China's growing demand for BIM specialists (36). The framework was developed in response to requests from 17 practitioners and academicians to integrate BIM into the curriculum of higher education, specifically construction management programs. This study summarizes the curricula at the top of the knowledge unit. It provides information on the influence of the supporting curriculum in civil engineering and management (CEM) on undergraduate BIM education. In the meantime, three objects must be considered to develop the curriculum: (a) pedagogical design, (b) teaching resources and materials, and (c) curriculum assessment. Another research researched modifying the CEM curriculum to integrate BIM. Their research aims to design curriculum-based instructional instruction and present the approach's advantages as an example to the undergraduate education community (37). Challenges encountered in this study included the mastery of BIM software and its administrative fields and the identification of several computer equipment requiring maintenance. In line with the development of the BIM curriculum, several studies have developed BIM courses with a series of learning frameworks and learning methods to teach building engineering students BIM-related competencies. Developing a course at the School of Civil Engineers of Ciudad Real have done to demonstrate the use of the BIM methodology in teaching Water Management-related project work subjects (Universidad de Castilla-La Mancha, Spain) (38). Sanchez-Ramos utilizes project-based learning for the subject Project Work "River and Water Management" (12 ECTS credits), which is in its fourth year and focuses on Hydrology.

Training activities include (a) fieldwork, (b) seminars and supervised work, (c) the resolution of practical cases, (d) the preparation of interim and final reports, and (e) the presentation and defense of the student's work. Students developed a 3D model of the Wastewater Treatment Plant (WWTP) they proposed for the city of Cártama as part of the BIM implementation. The results did not allow for the BIM tool to be enhanced, but they are quite positive and promising for future courses. A suitable BIM course for the construction and engineering undergraduate program has created by employing a systematic course development strategy comprised of three stages: preparation, development, and improvement (39). Identifying the precise needs of construction students is the initial step in preparation. The research also utilized project-based learning to incorporate BIM into construction management courses. This project-based learning method is utilized frequently in several reviewed articles. Several steps during the course development phase have taken, including preparing the basic framework, determining learning objectives, selecting learning topics, developing instructional strategies and assessment plans from a pedagogical perspective, and creating the course's final syllabus (39). In the final phase, evaluation and improvement exercises were conducted based on the input and comments of four BIM experts from the construction industry and four construction professors who have taught BIM-related courses in construction education. Ahn concluded that the course would acquaint construction students with BIM and its application in building projects. A case study on the BIM course capture the complexities of real-world construction projects in digital media, focusing on learning models that involve virtual collaboration, problem-oriented project-based learning, and role-based learning (40). Two instructors teach courses from two universities collaborating on lesson planning and delivery. A realistic depiction of the situation is required for students to benefit from collaborative and experimental learning in CEM education. Role-based learning is used in a multidisciplinary team setting to create real-world contexts through real-world projects. The roles included architect, structural engineer, mechanical engineer, scheduler; estimator, project manager (PM), construction manager (CM), and contractor are covered in training. The difficulty of the Becerik-Gerber research lies in the disparity between the aptitude and skill levels of students at each institution (40). Students find the workload, such as modeling difficulties, and the time required to complete each task to be excessive. The observations indicate that virtual collaborative BIM learning is advantageous for both universities. Additionally, instructors identify positive learning trends across assignments and reports. The use of role-based learning in BIM research was also conducted by previous research (41) in The Construction Management program at California State University, Fresno's 'Green Building Design' course. Teams of four or five students from two classes consist of a LEED consultant, a BIM project coordinator/manager, a design professional, an owner representative, and a project engineer (optional). At the beginning and end of the semester, online entry and exit surveys are administered to evaluate students' knowledge of BIM implementation and green building design strategies. According to the survey results, the joint course project had a significant positive effect on students' comprehension of the fundamental concepts of BIM and green building, confirming the efficacy of the instructional strategy. Survey-based research at the Civil Engineering Study Program at Curtin University in Perth, Western Australia, to investigate how students perceive their learning experiences when using BIM (42). Previously, students were instructed on BIM development and then practised creating 3D models containing information about structural materials, structural components, and structural forms. Students are required to consider construction scheduling, material supply, plant, equipment, human resources, and site infrastructure throughout the process. They surveyed 90 fourth-year students to determine their learning experiences. It is evident from the survey results that student are interested in learning advanced BIM-based tools to support project-based learning. Students performed exceptionally well with the assigned tasks and received an average of 80% on the group assignments. Creating coordination and collaboration learning modules to reveals additional BIM implementations in learning (43). Students from the Construction Management and

Engineering Graphics programs at the Illinois Institute of Technology are involved in the study (IIT). The collaboration module teaches BIM designers BIM concepts and the project lifecycle. Meanwhile, the coordination module is intended for BIM-based construction. Each module includes a series of topics and assignments that include practice with various software and technologies as learning tools, including Bentley BIM, Graph iSOFT ArchiCAD, and Autodesk Revit. This study is limited to the development of learning modules; therefore, it does not explain how students perceive the module's development. BIM-integrated learning media is another form of BIM implementation in building engineering education. In their study, a digitalization model in the form of Augmented Reality (AR) (44) has also developed for science education (45) and vocational education sector (46). This model is utilized in Turkish universities' third-year "Building Construction Project" courses. Students are tasked with designing a residential structure and digitalizing the image using augmented reality. Seyman Guray and Kismet demonstrated that the research was deemed beneficial, highly motivating, and improved construction detail perception. AR-related research by integrating AR to visualize building information models and evaluating existing AR tools (47). According to their research, current AR devices and BIM-AR applications are limited in terms of efficiency, precision, and development. Other than AR, virtual reality (VR) is used to implement BIM in building engineering education. In their research, a virtual reality (VR) platform for detailed construction that offers risk-free experiential learning (48). The validation results demonstrate that virtual reality is an effective educational medium for motivating and enhancing students' learning experiences. Moreover, using VR as a medium can improve learning outcomes compared to traditional paper-based learning.

Moreover, a virtual reality (VR) interface for pre-university students has designed in which users can navigate through 3D models of actual buildings and discover typically hidden construction solutions (49). The interface is primarily intended for pre-university and first-year students, as their understanding of Civil Engineering topics is still quite limited. Despite the lack of realism in the graphics, the VR interface can achieve the primary goals of the various Civil Engineering elements and display the modelling time. The perception of VR students was not investigated in this study. Then, the result about the influencing factors for the success of BIM implementation in building engineering education. Students can learn how to use BIM as a technology in the AEC industry through hands-on experience with cutting-edge technology and BIM-supporting software, as well as by collaborating on a team or individual project assignments (50). In the meantime, VR, AR, and a variety of BIM-supporting software are all media that aid in implementing BIM. VR and AR as media can effectively improve the learning experience, learning outcomes, and the perception of construction details (44,48). Meanwhile, in their study, Revit and Navisworks as software have used to introduce BIM technology in building engineering learning (39). The absence of diverse BIM support tools can impede the implementation of BIM in educational settings (51). In their research, computer equipment was not functioning properly and exhibited numerous maintenance issues (37). Therefore, it is crucial to consider 'advanced technology and various BIM support tools' when implementing BIM in building engineering education. In addition to the learning framework and curriculum design, the success of BIM implementation in building engineering education is also impacted by the learning framework and curriculum design. In addition to using augmented reality, virtual reality, and BIM tools, the current curriculum must be updated to reflect the most recent advancements in the construction industry (44). Curriculum modification is crucial in determining which BIM technology implementation efforts are most successful in various contexts (39). A proper BIM curriculum consists of an effective learning structure. Their study requires the proper learning framework to incorporate BIM into the modified curriculum to meet the operational industry's needs (36). In addition to aspects of the learning framework and curriculum design, the success of BIM implementation in building engineering education practice is also influenced by the enhancement of academic-industry partnerships. This statement is supported by previous research, which indicates that enhanced partnerships may be a means to advance BIM

education and BIM talent acquisition in the AEC industry (52). Increasing academic-industry partnerships will increase BIM professionals' contributions to bridge the gap between theory and empirical experience (43). Moreover, technical support networks are frequently a resource issue at universities. Partnerships with software vendors and industry consultants offer potential solutions to these problems (40). Additionally, student motivation and interest influence the success of BIM implementation in learning. Motivating students to take advantage of opportunities to learn BIM software operation is essential (51). Motivating students can increase BIM awareness among building engineering graduates (53). Students were enthusiastic and agreed that learning BIM technology would benefit them (42). They favoured beginning their education as early as the first year. This demonstrates that the motivation and interest of students substantially impact the success of BIM implementation. Occasionally, students struggle to apply the learning framework and BIM curriculum to actual project assignments. Teaching BIM requires a high level of technical expertise in both disciplines and software, which is a formidable obstacle (37). This issue can be resolved through ongoing mentoring and a network of technical support from instructors, software vendors, and teaching assistants (40). Professional instructors who are proficient with BIM technology are required. In their study, teachers must be trained before implementing BIM technology in the classroom (38). Based on this statement, it can be concluded that instructor guidance significantly impacts the implementation of BIM in learning. Learning source is the final factor that influences the successful implementation of BIM in building engineering education. In his research, he created a learning module for BIM education (38). He argues that BIM learning modules can assist architects, engineers, and construction professionals in preparing for future industrial requirements. This demonstrates the necessity of the module as a learning resource for successful learning. This is supported by previous findings which indicate that the availability of suitable learning and teaching resources for BIM is crucial (54,55).

Conclusion

A systematic review of 27 selected works of literature related to the study of BIM Implementation in AEC education learning revealed that construction management was the primary application of BIM technology. Various types of research are conducted, such as curriculum development, BIM courses, learning media, learning modules, and project-based learning. The most influential factors in the success of BIM implementation in building engineering learning are the use of advanced technology and various BIM supporting tools, learning framework and curriculum planning, academia-industry partnership enhancement, student motivation and interest, instructor guidance, and learning sources. The results of this study can be used as consideration in integrating BIM technology in AEC education curriculum planning and lesson design. The findings of this study also propose certain best practices or pedagogical strategies to assist universities and educators in incorporating BIM into their teaching methodologies.

Abbreviations

AEC: Architectural, Engineering and Construction,
BIM: Building Information Modeling,
SLR: Systematic Literature Review.

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Author's Contributions

All authors are equally contributed.

Conflict of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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