







Review

A Systematic Review of Current Strategies and Methods for BIM Implementation in the Academic Field

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Abstract: Since the international governmental institutions required and/or recommended (according to the regulations of each country and continent) all public works to be certified in the BIM (Building Information Modeling) methodology, public and private institutions and universities have sought to integrate BIM into their production and educational processes. This requires the university academic environment to focus its efforts on training students in this methodology, as they will need to apply it in any future work activities related to architecture and construction. This article seeks to analyze which methods are being used by higher education institutions around the world to integrate BIM implementation in AEC (architecture, engineering, and construction) degrees and to determine if a set of regulatory guidelines exists that could serve as a common foundation for institutions to improve this integration process. To this end, a systematic literature review was carried out on WOS and SCOPUS by applying the PRISMA statement methodology. Inclusion and exclusion criteria were selected based on keywords, abstracts, and full content of the articles. In the end, 23 articles were thoroughly studied, the integration and evaluation methods analyzed, and results obtained. The analysis shows a consensus on the need to develop common academic guidelines across university centers that define a strategy for curriculum modifications and teaching and learning strategies. Finally, future lines of research are identified.

Keywords: education development; BIM implementation; AEC; construction; systematic review



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1. Introduction and Background

Building information modeling (BIM) is a working methodology for the management of building or civil works projects, in which all the agents involved in the process work collaboratively and throughout the life cycle of the building [1–4].

Although BIM technology has existed for more than two decades, implementation in construction processes has been relatively slow. Since governmental institutions began to require public works to be certified in BIM, the construction processes in this methodology began to spread [5]. BIM implementation has been led by countries such as the USA, UK, Germany, Canada, and France, joined shortly after by Australia, Brazil, and Japan, among others [6].

The U.S. has long been a world leader in this process [7]. In 2007, they ordered the use of BIM to validate spatial programs in all their projects and developed internationally recognized guidelines and standards [8]. The UK government introduced an implementation strategy considered to be the most ambitious centrally driven one in the world [9]: in 2011, through an implementation phase, the UK required that, by 2016, all government projects would require BIM [5]. In the Scandinavian region, countries such as Norway,

Denmark, and Finland are also world leaders in BIM adoption. They launched universal guidelines for the industry with the aim of establishing a standard in the European Union, and their development has had worldwide interest. They also invest heavily in research and development [5]. Other countries such as Singapore, Australia, Brazil, and China have also promoted initiatives, standards, and strategies to effectively implement BIM. Finally, we can consider that the European Parliament and Council Directives 2014/23/EU and 2014/24/EU of 26 February 2014 on public procurement established the need to use electronic systems in procurement processes for works, services, and supplies, as of September 2018 [10,11].

Therefore, the construction industry is showing an increasing interest in BIM, and the gradual acceptance of BIM is generating employment and opportunities for experts in this methodology [12–15]. BIM integration in companies means that new pedagogical strategies must be introduced into curricula to adequately train students and future members of the professional sector [16–18]. In other words, for future professionals to be competitive in BIM methodology, universities must be able to train their students today. For this reason, higher education institutions, as generators and promoters of knowledge [19], need to implement BIM in their curricula now.

Curricula have one objective, which is to provide students with the necessary competencies for their future professional work. It is necessary for institutions to train students such that they achieve the knowledge and skills necessary to meet the requirements of the construction industry. The incorporation of BIM in architecture, engineering, and construction (AEC) degrees should not change this objective or its content, but rather it should change the teaching/learning methodology [20]. The American Society of Architects (AIA) identified BIM as a “catalyst to rethink architectural education” [21,22].

Reflection is needed on how to strengthen the link between academic activities and subsequent professional practice and between institutional education and the practical requirements of the industry [23]. As previously mentioned, BIM processes in industry are based on collaboration and standardization. In other words, both BIM implementations and BIM collaborative work are supported by several standards, which are increasingly being used by public agencies. These help to streamline processes and facilitate collaboration between the different agents involved. Various publications have shown that for a future professional to work collaboratively, he or she must be educated in a collaborative manner, and thus the student must be brought closer to real practice. Therefore, if curriculum implementation is to be carried out, it must be in a collaborative manner. This means a curriculum based on standards. At this point, it should be noted that the discussion here addresses implementations in two different areas, work and education. Although these protocols are necessary in both areas, they do not necessarily have to be the same; however, they must be similar. For example, the work environment includes different disciplines and phases, which would correspond to areas of knowledge and academic courses in the academic environment.

Different publications have shown that the universities trying to implement BIM in their curricula, whether in architecture, civil engineering, or building degrees, are doing so with disparate and individualized proposals and are lacking the support of a common strategy or standards [24]. Such standards would help institutions make the leap to BIM by giving them guidelines to follow, which would speed up the process, and by providing good practices, as in the case of work with BIM methodology in industry.

For this reason, at the 2015 edition of the EUBIM congress at the Polytechnic University of Valencia, an academic BIM manifesto was agreed to be published, which requested an integrated and collaborative BIM training plan among all academic institutions at the national and international levels. Currently, such protocols or standards still do not appear to exist, although different authors show great interest in reaching a consensus on a common action protocol between different institutions, thereby saving time and effort and increasing the effectiveness and speed of integrating this type of methodology in the current curricula [25,26]. These studies consider the strategies adopted in different centers,

the resulting experiences, both positive and negative results, and their relationship with the professional environment [15,27,28].

Apart from the need for the unification of standards between institutions to achieve an effective implementation, it is important to point out that the incorporation of a methodology in a curriculum is not simply the teaching of different software. This methodology is based on technology, which is usually taught in Graphic Expression (GE) subjects. However, the objective is to use technology to improve construction processes and not just to learn the technological software. Therefore, each institution should take a unified approach across different areas of knowledge and not only in GE subjects [23,26,29].

Education is changing due to a technological movement to eliminate the barriers of information flow and an ideological movement to remove artificial barriers—those created by man [30]. The complexity of integrating BIM methodology implies that significant changes will be required in the AEC educational environment. The current scarce scientific research in BIM education has focused on deepening the technical criteria of implementation to the detriment of management aspects of the methodology, although the latter is probably more complex and important. This is a serious problem to consider if proper BIM application is desired [31].

This approach has led to a growing scientific literature in this field in recent years [17], which motivates us to conduct an exhaustive updated study of the literature to analyze the extent to which the process of implementation in the academic field of AEC is being scientifically researched and to check if there are protocols for institutions. This research is open to the whole world to determine how the different countries are working [15,25–28].

Within this framework, the document focuses on narrating the state of the art among higher education institutions (IESs) for integrating the BIM methodology. A systematic review of the literature is carried out to examine methods, practices, experiences, protocols, and results. The focus of the study is not to demonstrate the need to implement BIM in institutions, but to find out if the implementation processes are being evaluated and analyzed. The objective is to find out if a common standardized guideline exists or is being researched to help institutions train their AEC students to naturally integrate BIM into their future professional practice.

The most important differentiating fact of this article is to perform an updated systematic review that should help any institution to improve its own implementation proposal; this article both reviews and evaluates BIM implementation at the educational level. This review of the literature published in two of the main databases, WOS and SCOPUS, aims to learn about the different approaches and developments in different educational institutions, in the period from 2016 to 2020 (inclusive).

2. Materials and Methods

To validate the study, following the PRISMA statement (Preferred Reporting Items for systematic reviews and Meta-Analyses) [32,33], this chapter narrates the systematic review as carried out. A study was conducted to classify and analyze the concepts and issues in response to the research objectives using information found in existing publications to date, starting in 2016 and ending in December 2020.

A systematic review of the qualitative literature is carried out, where the concepts found are classified and analyzed through discussion, establishing qualitative relationships.

2.1. Research Objectives

The aim of this study is to answer a set of research questions by conducting a systematic review of the literature addressing the overall situation of BIM integration in education. Within the educational field, the study focuses on university education for AEC degrees, the field in which BIM implementation is required by industry.

The proposed research questions are:

- RQ1: What processes or strategies are being carried out to implement BIM in AEC degree curricula worldwide?

- RQ2: How is the feasibility of such strategies being analyzed?
- RQ3: Does an academic BIM implementation guide exist, or is one being researched to serve as a reference for educational centers?

It is important to bear in mind that each center has a different curriculum, and each country trains and executes its construction industry differently, so that strategies that are effective in one part of the world may be less so in another. However, it should be noted that the BIM methodology is being implemented globally [34–36] and students are increasingly studying abroad through Erasmus programs. Therefore, despite these differences, the objective is to identify and analyze those actions being undertaken by AEC degree faculties to help institutions, centers, and teachers facilitate the training of current students. Individual actions or those in collaboration with universities, reviews of curricula, experiences of students and teachers, and protocols or action strategies are sought.

For the search in WOS and Scopus, studies similar to this research are also sought, although literature reviews aimed at implementing BIM in university degrees were discarded in the final selection, as they did not provide answers to the specific objectives of this research.

2.2. Search Strategy

To carry out the systematic review, congress articles or papers were considered from 2016 to the present, December 2020, at the university educational level; selected papers focused on the development of new technologies and, specifically, on the development of BIM implementation in AEC degrees. For this purpose, and considering their relevance in the educational area, the WOS and SCOPUS databases were analyzed. The search started initially by combining the four following keywords: BIM, Building Information Modeling, University, and Students. Numerous articles were obtained, most of which were not directly related to the educational field due to the large number of BIM implementations studied at the professional or company level. Therefore, it was decided to include a fifth search word, 'Education', on both platforms to focus the results on the area of interest for this study, as shown in the Table 1.

Table 1. Search terms and fields.

Database	Search Terms	Fields
WOS	BIM AND "Building Information Modeling" AND Education and University AND Students	Topic
SCOPUS		Title-ABS-Key
WOS complete search	(BIM) AND Topic: ("Building Information Modeling") AND Topic: (Education) AND TEMA: (University) AND Topic: (Students). time frame: 2016–2020.	
SCOPUS complete search	TITLE-ABS-KEY (BIM) AND TITLE-ABS-KEY ("Building Information Modeling") AND TITLE-ABS-KEY (Education) AND TITLE-ABS-KEY (University) AND TITLE-ABS-KEY (Students)) AND PUBYEAR > 2016 AND PUBYEAR < 2020	

To assess the relevance of each study, content-based inclusion and exclusion criteria were established. First, duplicate articles were identified and excluded. Second, studies that did not report on BIM in AEC education in their title or keywords were eliminated. Subsequently, the abstracts were read, and those that were not related to the academic or educational field were eliminated. Finally, the full text of the remaining manuscripts was reviewed, and those that discussed strategies adopted to design and implement BIM specifically in AEC curricula were selected. The stages carried out were the following:

1. Execution of queries in WOS and SCOPUS using the keywords BIM, Building Information Modeling, Education, University, and Students yielded 89 results.
2. Elimination of duplicate articles reduced the results to a total of 68.
3. Review with respect to titles and keywords (applying the inclusion and exclusion criteria).
4. Review with respect to abstracts (also applying the inclusion and exclusion criteria).
5. Extensive review and quality assessment (also applying inclusion and exclusion criteria).

2.3. Inclusion and Exclusion Criteria

The aim was to identify documents that explained how the integration of these methodologies is developed in curricula. As already mentioned, the search was carried out with the keywords BIM, Building Information Modeling, Education, University, and Students to reduce the number of articles related to BIM implementations in companies. Once the search was carried out, we found that articles that did not match the search criteria of the titles and keywords were those that did not directly relate BIM to the AEC environment. Afterwards, a review of the abstracts was made to discard those that did not refer to education in general or that only considered one of the specific objectives, including BIM integration in industry, among others. Subsequently, after a complete review of the studies, those not related to higher education and/or the main objective, which is the development of BIM implementation in AEC degrees, were also excluded. In this final review, those studies related to other training, such as academy courses, masters, or vocational training, were discarded. It is important to note that in addition to architecture and building studies, civil engineering and construction management studies were included in the criteria of this search because they are fields in the same sector (AEC) in other countries. Finally, the authors of this manuscript worked in parallel in all phases to achieve greater reliability of the study.

2.4. Trial Flow/Selection Criteria

As shown in Figure 1, the initial search identified 89 articles for review considering both databases, with 68 remaining after eliminating repetitions. In the first stage, titles and keywords were reviewed to perform the first filter, and 12 articles were removed. Subsequently, a review of the abstract of the articles was carried out, and 9 articles that were not directly related to the study were eliminated. Finally, a complete reading of the documents was carried out, and 24 additional articles were removed because their objective was not related to the methodology and implementation process for the specific educational level. After the full-text review, those literature reviews and theoretical studies without results addressing the direct application of the methodology in the university educational setting were also discarded.

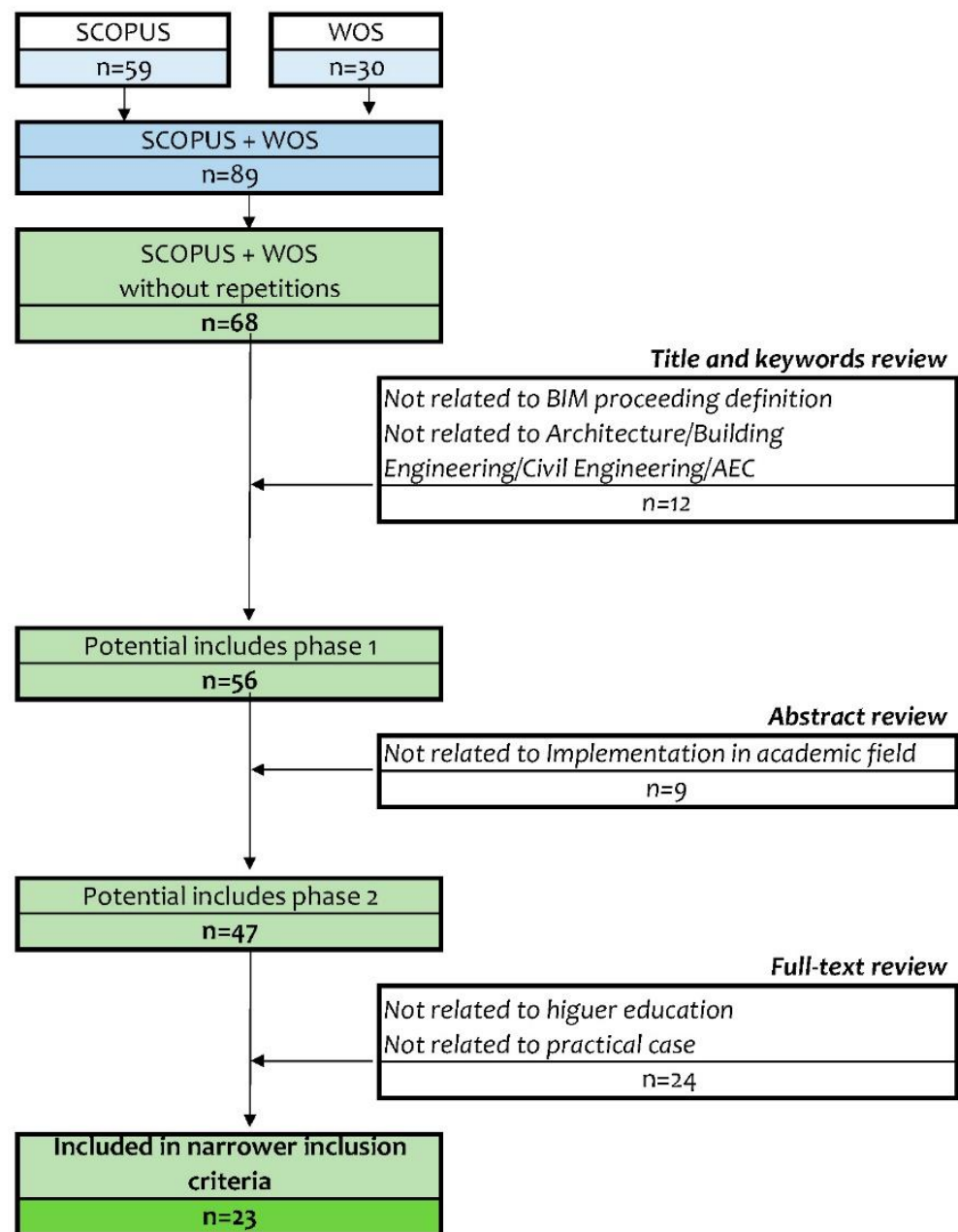


Figure 1. Selection process flow diagram.

3. Results

The research indicators were identified to analyze the selected articles. As shown in the following sections with graphs, tables, and conclusions, the indicators were divided into four sections to study the most relevant information: study descriptors (origin, year of publication, type of document, keywords, place and scope of application, type of technology), type of intervention (protocols or integration strategies), evaluation methods (methods for analyzing teaching results), and content of the study (objective, method and results).

3.1. Study Descriptors

Once the full-text review was completed and, following the aforementioned search criteria, 23 articles were selected. Before reading, the important concepts for obtaining information were categorized to carry out the subsequent data analyses. First, as observed in Figure 2, there has been significant growth in terms of the publication of articles in the

field of study since 2018. The study ended in December 2020, so the graph data correspond to full year information, where we can observe a progressive increase in publications on this issue. The impact caused by the COVID-19 pandemic in the graph data must be taken into account, since it may have affected the 2020 results.

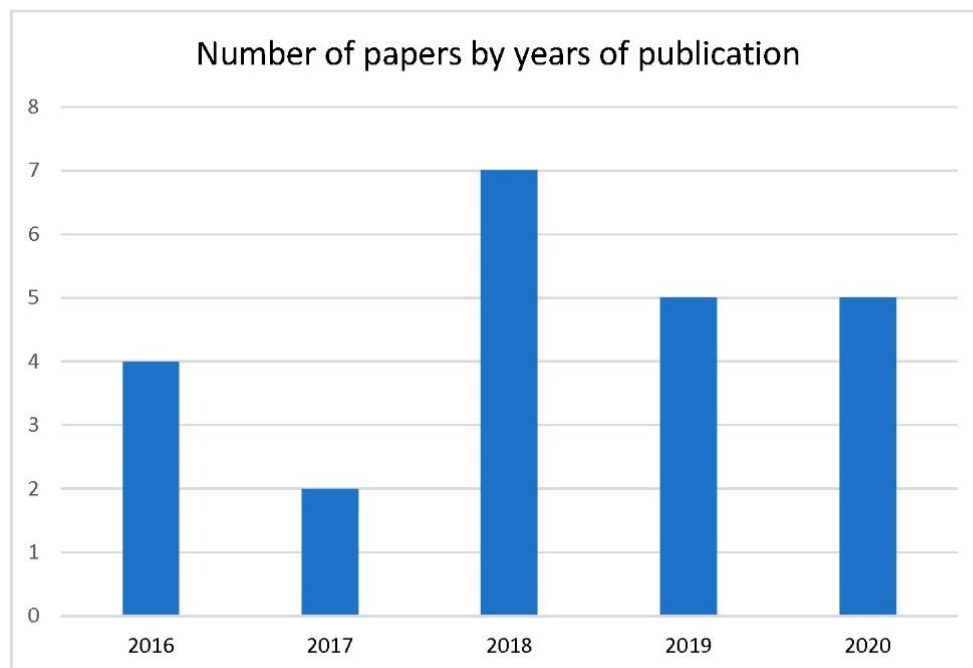


Figure 2. Number of published documents per year of publication.

Table 2 shows journals or conferences of the different publications and the research country. It is necessary to understand how the BIM implementation process is being carried out in the AEC educational field at a global level, so a general study was conducted by expanding the search to a worldwide level. There is a great heterogeneity in the countries with publications in this field of study; therefore, taking into account the type of education in each country, it is difficult to determine which articles are most relevant for the application of this methodology in Spain. As seen in Table 2a, the affiliation of authors is wide and diverse. Ranked from highest to lowest, there were 5 items from the US, 3 from China, and 3 from the UK, and 12 other countries had 1 publication (5 from Europe, 2 from North America, 2 from the Middle East, 1 from South America, 1 from Australia, and 1 from Russia). As shown in Table 2b, 3 articles were presented and published at the ASEE Annual Conference and Exposition; 2 in Engineering, Construction and Architectural Management; 2 at the IEEE International Conference on Emerging eLearning Technologies and Applications; and 2 in the Journal of Information Technology in Construction; the remainder were published in 14 different journals and proceedings.

3.2. Type of Interventions

This section attempts to answer the first research question: what processes or strategies are being undertaken to implement BIM in AEC degree curricula worldwide? To search for results, it was important to classify the publications by type of intervention and thus draw comparisons and identify similarities. As seen in Table 3, the classification was made considering 4 types of intervention: (A) academic guides, (B) review of curricula, (C) design of own plan/protocol, and (D) incorporation in a course/project/activity. These are detailed below:

- (A) Academic guides: academic guides are written for students and/or faculty to support the BIM learning process in EGA subjects and/or others.
- (B) Curriculum revision: the curriculum or part of it has been revised and/or modified for better BIM integration.
- (C) Design of plan/protocol: an own plan/protocol for BIM implementation has been designed directly linked to the educational system of the center.
- (D) Incorporation in a course/project/activity: BIM teaching has been introduced in a compulsory or optional subject, in a transversal project or in a specific activity (competition, external course, and so on).

Table 2. Researcher affiliation and publication's journal/conference.

Doc.	Research Country	Doc.	Journal/Conference
[37–41]	EEUU	[42]	Acta Polytechnica Hungarica
[43–45]	China	[46]	Applied Sciences (Switzerland)
[47–49]	United Kingdom	[47]	Architectural Engineering and Design Management
[30]	Canada	[38,40,50]	ASEE Annual Conference and Exposition, Conference Proceedings
[51]	Poland	[23]	Australasian Journal of Engineering Education
[52]	Emirates	[30]	Canadian Journal of Civil Engineering
[53]	Croatia	[43,48]	Engineering, Construction and Architectural Management
[54]	Norway	[53,55]	ICETA 2018—16th IEEE International Conference on Emerging eLearning Technologies and Applications, Proceedings
[50]	Mexico	[45]	International Journal of Engineering Education
[46]	Spain	[54]	International Journal of Sustainable Development and Planning
[56]	Brazil	[56]	Journal of Civil Engineering Education
[55]	Slovakia	[49]	Journal of Engineering, Design and Technology
[57]	Turkey	[39,41]	Journal of Information Technology in Construction
[23]	Australia	[44]	KSCE Journal of Civil Engineering
[42]	Russia	[57]	MEGARON/Yıldız Technical University, Faculty of Architecture E-Journal
		[37]	Proceedings, Annual Conference—Canadian Society for Civil Engineering
		[52]	Universal Access in the Information Society
		[51]	World Transactions on Engineering and Technology Education
(a)		(b)	

All purely theoretical studies and those without real interventions were discarded because the aim of this review is to evaluate the procedures and results of the proposals rather than to raise the need for such integration.

Table 3. Classification of the papers selected by type of intervention.

Authorship—Type of Intervention	A	B	C	D
Boton, Forgues, Halin (2018) [30]		X	X	X
Comiskey, McKane, Jaffrey, Wilson, Mordue (2017) [47]				X
Ferrandiz, Banawi, Peña (2017) [52]				X
Hailer, Cribbs, Kline (2019) [37]			X	X
Jin, Piroozfar, Wanatowski, Tang (2018) [43]				X
Jin, Zou, Piroozfar, Bo, Painting (2018) [48]			X	X
Lassen, Hjelseth, Tollnes (2018) [54]				X
Lee Davis, Vassigh (2018) [38]				X
Leite (2016) [39]	X			X
Mesároš, Mandičák, Vukomanović, Kolarić (2018) [53]				X
Otey, Camba, Daney (2019) [40]			X	
Palomera-Arias, Liu (2016) [41]		X		X
Sanchez, Ballinas-Gonzalez, Rodriguez-Paz, Nolasco-Flores (2020) [50]				X
Sánchez, Gonzalez-Gaya, Zulueta, Sampaio (2019) [46]		X	X	X
Sotelino, Natividade, Travassos do Carmo (2020) [56]		X	X	X
Struková, Bašková, Krajníková (2018) [55]				X
Swallow, Zulu (2019) [49]				X
Türkyilmaz (2016) [57]				X
Vimonsatit, Htut (2018) [23]				X
Wang, Yan, Fan, Jin, Yang, Kapogiannis (2020) [44]				X
Zakharova, Kruglikov, Petunin (2020) [42]			X	X
Zhang, Zhao, Wang, Li, Huijser (2020) [45]				X
Zielinski, Wójtowicz (2019) [51]				X

In the results, it can be observed that most of the works deal with interventions related to the incorporation of the methodology in a specific project or activity within a course. By contrast, it can be observed that only 4 of the publications propose the complete revision of the curriculum, and only 1 proposes the realization or modification of the syllabus to help in the integration process.

3.3. Evaluation Methods

Another relevant aim that is closely related to the previous one was to obtain information on how these interventions have been evaluated and thus answer the second research question: How is the feasibility of these strategies being analyzed? As shown in the Table 4, it was decided to classify these publications using the following points as common processes in teacher evaluations: (A) project-based learning (PBL), (B) experiences through surveys, and (C) experiences through interviews. These are detailed below:

- (A) Project-based learning: the students' learning process is analyzed through their evolution and/or comparison of grades.
- (B) Experiences through surveys: the results of student and/or faculty satisfaction surveys are analyzed.
- (C) Experiences through interviews: The results are analyzed through interviews with students and/or teachers.

The publications that evaluated their interventions through surveys stand out as the most common; most of them focused on students, and only some of them focused on students and teachers. On the opposite side, few evaluations through interviews are observed. In a more central position are articles focusing on integration through PBL and subsequently evaluating students and teachers in the form of surveys.

Table 4. Classification of the papers selected by type of evaluation.

Autorship—Type of Evaluation	A	B	C
Boton, Forgues, Halin (2018) [30]	X	X	
Comiskey, McKane, Jaffrey, Wilson, Mordue (2017) [47]	X		
Ferrandiz, Banawi, Peña (2017) [52]		X	X
Hailer, Cribbs, Kline (2019) [37]		X	
Jin, Piroozfar, Wanatowski, Tang (2018) [43]	X	X	
Jin, Zou, Piroozfar, Bo, Painting (2018) [48]		X	
Lassen, Hjelseth, Tollnes (2018) [54]		X	
Lee Davis, Vassigh (2018) [38]		X	X
Leite (2016) [39]	X	X	
Mesároš, Mandičák, Vukomanović, Kolarić (2018) [53]		X	
Otey, Camba, Daney (2019) [40]		X	
Palomera-Arias, Liu (2016) [41]		X	
Sanchez, Ballinas-Gonzalez, Rodriguez-Paz, Nolazco-Flores (2020) [50]	X	X	
Sánchez, Gonzalez-Gaya, Zulueta, Sampaio (2019) [46]	X	X	
Sotelino, Natividade, Travassos do Carmo (2020) [56]	X	X	X
Struková, Bašková, Krajníková (2018)[55]	X	X	
Swallow, Zulu (2019) [49]		X	
Türkyilmaz (2016) [57]		X	
Vimonsatit, Htut (2018) [23]	X	X	
Wang, Yan, Fan, Jin, Yang, Kapogiannis (2020) [44]	X	X	
Zakharova, Kruglikov, Petunin (2020) [42]	X		
Zhang, Zhao, Wang, Li, Huijser (2020) [45]		X	X
Zielinski, Wójtowicz (2019) [51]	X		

3.4. Study Content: Objective, Developed Method and Results Obtained

This section reviews the content of the 23 articles analyzed. The main objective of the study and the two previous points, the explanation of the main method used and the type of evaluation for each case, were investigated individually and in detail. The results obtained by the authors, both positive and negative, are included above.

However, we also aimed to determine if these studies carried out any type of evaluation focused on analyzing their BIM integration method to give it validity and to answer the third research question: Does a guide to an academic BIM implementation that can serve as a reference for schools exist, or is one being investigated?

In this section, see Table 5, it is necessary to clarify that studies that aim to demonstrate that BIM is necessary in universities are not the focus. We are looking for cases that have evaluated the implementation process itself over a period or have made comparisons between different implementation strategies that can lead to best practices that other institutions can benefit from. Therefore, we are also looking for studies that have worked on or researched a common standardized guideline.

Table 5. Classification of the papers selected by method and results in the papers.

Authors, Year, Reference, and Summary Description. Developed Method and Results Obtained.

Boton, Forgues, Halin (2018) [30] carry out a theoretical and reflective study on implementations in the academic field based on competencies. Then, they make a proposal for a curriculum and offer a cross-sectional case study involving students, teachers, and researchers. Moreover, they participate with the industry, seeking bidirectionality between industry and university.

- **Method:** They propose a framework composed of three main aspects: the skills that students must acquire, the teaching approach to be adopted, and the implementation strategy. The first defines the competencies, the level of education, and specific BIM knowledge; the second defines teaching methods, evaluation, and technological environment; the third offers a first approximation, timing, and a discussion of bidirectionality with industry. With this proposed framework (constantly evolving and improving), a case study is carried out and both groups, industry and university, are evaluated.

Table 5. Cont.

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- **Results:** The framework proposed by the authors can serve as a guide for other universities and support synergy between different institutions, since it encompasses all the necessary aspects for the integration of BIM in the university. The gradual approach adopted for continuous improvement is a positive aspect; they demonstrate the effectiveness of the two-way exchange between industry and university and emphasize the need for links between teachers and BIM researchers to keep the content program up to date. Regarding the limitations, they highlight the lack of participation of university administration and management. The fragmentation between research, teaching, and pedagogical structures also does not facilitate this type of change, so the support of management and administration is key to overcoming resistance to change.
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- Comiskey, McKane, Jaffrey, Wilson, Mordue (2017) [47] conduct a longitudinal study that experiments with three different collaborative environment platforms for the delivery of a multidisciplinary BIM project to undergraduate students, as they considered that BIM integration was meaningless without a collaborative work approach.
- **Method:** Over a period of three years, descriptions of experiences are captured to understand the benefits and drawbacks of the different data exchange platforms in an academic environment. A thematic analysis method is used to identify trends and outline problems across platforms. Subsequently, a synthesis of crossover cases is conducted to analyze the specific conclusions. Initially, they would develop a single module with common learning outcomes for all students that is independent of the curriculum design. However, such a module creates assessment challenges, as the ratings and key aspects of the collaborative environment are not similar.
 - **Results:** The study is based on data exchange platforms for BIM integration in the academic environment. As a starting point, it is a useful example, since they show not only the use of the different tools but also the interoperability of software and collaboration between actors, the basis on which BIM is established. They also recommend the use of BIM execution plan (BEP) documents or guidelines to support these types of processes.
-
- Ferrandiz, Banawi, Peña (2017) [52] conduct a study focused on BIM implementation in a construction course within the AEC curriculum to see if the course needs to be modified to adapt to this new technology. The focus is not the global implementation of BIM in the curriculum but the change from CAD to BIM in a specific area.
- **Method:** The course is divided into three groups of students to compare their performance; the variable is introduced into one group. A pretest is carried out and when the course is completed, the students are interviewed to understand their motivation/satisfaction.
 - **Results:** As students improve their software skills, their motivation to use these technologies increases. The study covers a concrete construction course and does not mention changes in the curriculum or implementation protocols in a transversal way.
-
- Hailer, Cribbs, Kline (2019) [37] perform, with a great variety and interoperability of software, a comparison between two schools that carry out different incorporations of BIM in their curricula, and thus provide a basis for developing a standardized and integrated curriculum with BIM.
- **Method:** Both schools present a thematic scheme for the introduction of BIM in their curriculum; they use similar software and share a similar pedagogical approach, since these two schools usually collaborate. Subsequently, students apply the knowledge in laboratory sessions. There are some differences in method. The laboratory in one of the schools is a space dedicated to BIM, while in the other, it is open to all specialties involved in the degree. The results are analyzed through surveys and evaluations of the students.
 - **Results:** Although the foundation of the implementation is similar, there are small differences between the schools. Comparisons between them have been helpful, and they stress the importance of continued comparisons to regularly refine the teaching materials. This study demonstrates the importance of collaboration between different institutions for the best integration of BIM in the educational field.
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- Jin, Piroozfar, Wanatowski, Tang (2018) [43] carry out a study aiming to present a pedagogical practice of project-based learning through BIM interoperability in interdisciplinary buildings.
- **Method:** A comprehensive study of previous pedagogical cases, a literature review of BIM-based education is carried out. Subsequently, an interdisciplinary project is conducted between different teams from different AEC disciplines as part of a case study and to compare the perceptions of students with those of industry professionals.
 - **Results:** The study shows the ability of BIM to allow interdisciplinary collaboration in different areas and improve communication. However, there were pedagogical limitations regarding interoperability between software products. The study focuses on how interdisciplinary PBL improves BIM learning and not on evaluating integration methods for the curricula.
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Table 5. Cont.

Jin, Zou, Piroozfar, Bo, Painting (2018) [48] compare three schools in different countries that had used BIM actively for several years; the objective is to seek synergy between them to demonstrate the lack of inter-institutional coordination and strengthen the connection between institutional education and the practical needs of the industry.

- **Method:** This study uses a case study to compare the methods and perceptions of three countries: UK, Australia, and China. The cases are conducted with representatives of the main universities in their home country who had been actively implementing BIM in recent years and were interested in carrying out BIM pedagogical research. It includes teaching content and the evaluation methods of each of the institutions to see how the pedagogical approach affects students' perceptions.
- **Results:** This study is interesting because it explains the different methods applied in each university and offers a subsequent comparison of the students' perceptions, taking into account demographic and pedagogical differences. The authors show the differences in results between the three institutions and highlight the need for a closer connection between educators and institutions to establish a more solid joint vision. This study could serve as an example for universities that are in the implementation process.

Lassen, Hjelseth, Tollnes (2018) [54] analyze BIM integration in two study programs (Civil and Structural Engineering and Energy and Interior Environment in Buildings) where students take an introductory course to familiarize themselves with collaborative and technological work in the industry.

- **Method:** The introductory course of 10 ECTS takes place in the first semester, and the analysis method is based on data collected from a questionnaire and a course evaluation aiming to determine the knowledge and skills acquired.
- **Results:** The authors highlight, from the students' perception, the importance of collaborative work. The results of BIM integration are shown in an introductory course and, although they are satisfactory, this study is not focused on analyzing the integration methods or protocols.

Lee Davis, Vassigh (2018) [38] present an interdisciplinary research project that involves students of Architecture, Construction, and Mechanical Engineering integrating virtual and augmented reality technologies with BIM. It focuses on experiential learning and the importance of interdisciplinary collaboration.

- **Method:** The project consists of a control group and two experimental out of three independent courses in all disciplines of Architecture, Construction, and Mechanical Engineering taught within their home departments with instructors from specific disciplines. Pre- and post-surveys are conducted to assess collaborative learning and post-surveys are conducted with students to assess satisfaction with the courses.
- **Results:** Collaborative learning that involves cross-domain and interdisciplinary interactions can be challenging to implement, but with the right guidance and tools, they improve collaborative learning in areas where team interaction is essential. The study is focused on using AR-VR in interdisciplinary teams: it does not perform an analysis of BIM implementation methods/protocols in the curricula.

Leite (2016) [39] describes a PBL course carried out since 2010 and in continuous improvement where students acquire BIM knowledge.

- **Method:** Instructors add new content each course through their research in the field. The course, unlike those in previous years, is oriented toward methodology and toward understanding BIM as management processes and not only a technology. The focus is not the software. The study shows in detail the organization of the course (industry conferences, case studies, theory, and practical sessions) and educational methods (learning objectives, rubrics, and assessments). An evaluation based on rubrics and surveys is carried out at the end of each laboratory for students and teachers.
- **Results:** The participation of the industry, the PBL and the relationship between research and continuous teaching improvement are important points to consider for the improvement of BIM learning. Focusing the implementation of BIM processes and not on knowledge of the software can be helpful for other institutions in the process of BIM implementation.

Mešároš, Mandičák, Vukomanović, Kolarić (2018) [53] carry out a comparison of BIM use in industry in Slovakia and Croatia and subsequently compare the BIM delivery of two universities, one Slovak and the other Croatian.

- **Method:** They carry out an initial theoretical analysis of conducted surveys and explain in detail the differences found in the teaching of BIM in both universities, taking into account the differences that exist in industry in each country.
- **Results:** Slovakia is at a very early stage of BIM adoption; they have improved BIM teaching in education, but the knowledge is still more theoretical than practical. Zagreb only offers one course, so there is a lack of integration across more courses, and there is a lack of knowledge about coordination, interoperability, and conflict detection. As a starting point, the previous comparison between the industries of both countries is interesting in the later comparison of the academic results from the two universities. However, the study does not deepen its comparison of the integration methodologies between both universities.

Table 5. Cont.

Otey, Camba, Daney (2019) [40] find that including BIM in the graphic department was important but not sufficient. The authors design an implementation plan in the curriculum focused on buildings with territorial development.

- **Method:** Several versions of the implementation design were developed, a curriculum map was created, and instructors from other areas were included in discussions so that the faculty could help in the development of new BIM classes. Templates were also created for other subjects, and laboratory hours were offered. The updates to the implementation plan were analyzed through surveys.
- **Results:** Students improved visualization skills, among other competencies. However, there were difficulties in integration. Graphics subjects did not have sufficient credits, and extracurricular courses could not be included in the curriculum. Teachers in different areas did not want this type of integration in their subjects due to a lack of time and because they were not familiar with the different technologies, so students were allowed to decide whether to use these technologies or not. The study emphasizes the need for collaboration and proposes solutions to the common difficulties experienced in this type of integration in the curricula. It can offer support to other institutions.

Palomera-Arias, Liu (2016) [41] present a modification of the curriculum to include BIM in Construction Science and Management. They also explain in detail the laboratory course, what it looked like without BIM and what it looks like, since 2015, with BIM.

- **Method:** The integration is addressed through three courses. The first is fundamental BIM concepts in the 3rd year; subsequently, students carry out a laboratory exercise including Mechanical, Electrical, and Plumbing Systems (MEP); and finally, students must use BIM in their final project. Students' perception is evaluated through surveys and assessments.
- **Results:** Most students feel that BIM is a positive part of the course, that problems lead to learning, and that knowledge of BIM and MEP systems are necessary skills in their profession. The article explains how the curriculum for BIM integration is modified but remains focused on results related to the perception of students regarding BIM-MEP learning; it does not focus on the objective of this study, which is to analyze the integration methods/protocols.

Sanchez, Ballinas-Gonzalez, Rodriguez-Paz, Nolasco-Flores (2020) [50] analyze the use of BIM to improve education in sustainable building design through PBL, with the long-term plan being to develop an alternative curriculum.

- **Method:** First, students approached the literature on BIM. In the second stage, students developed a project with a cross-citizenship approach that was evaluated through an established rubric. Subsequently, a satisfaction survey was carried out to evaluate the results.
- **Results:** The results show a 20% improvement in student learning outcomes and demonstrate the effectiveness of using BIM as a teaching tool. The study can serve as a basis for an initial map in the early stages of implementation, since the student is integrated from the beginning, prior to the development of the project.

Sánchez, Gonzalez-Gaya, Zulueta, Sampaio (2019) [46] carry out a proposal for the incorporation of BIM in various industrial engineering degrees and subsequently analyze the results of the different itineraries.

- **Method:** The implementation is done in two phases: first, compulsory training in the 2nd year of all degrees in industrial engineering; and second, optional specialized training in the 4th year of different degrees and compulsory training in one degree program. The authors show how the different learnings come together according to the student's itinerary and explain the process in detail. Later, they exhaustively analyze perceptions according to phases and knowledge.
- **Results:** The results are positive; they also emphasize the need to continue evaluating future courses to test the validity of their proposals. The article responds to the initial objective of this study, as it can serve as an example of proposed implementation processes with different student itineraries.

Sotelino, Natividade, Travassos do Carmo (2020) [56] culminate with this article reviewing a six-year experience of a BIM implementation across several degree programs and describe the challenges and successes of the approach adopted. The work is part of a larger effort to incorporate the concept of IPD and BIM into the curriculum at the Pontificia Universidade Catolica do Rio de Janeiro (PUC-Rio) and to develop an alternative curriculum.

- **Method:** They aim to empirically understand how BIM teaching will affect students in their professional lives. They explain the long-term objective and the development of the pilot course that was offered in 2012. Then, they show the challenges and successes of the approach adopted through an analysis carried out with students through surveys in interview format. They end by discussing a future line of study that they are already working on, a new BIM AEC-based curriculum that will influence engineering and architecture disciplines.
- **Results:** They highlight the lack of adequately trained BIM staff and the inability to understand that BIM is a methodology. They emphasize the need for the correct and structured identification of competencies and the importance of considering a BIM education as a shared responsibility between academia and industry in order to implement BIM efficiently. The article responds to the object of this study, as it can serve as an example for other institutions in the same situation.

Table 5. Cont.

<p>Struková, Bašková, Krajníková (2018) [55] present a study where the objective is to analyze motivational activities to improve graduates' BIM awareness.</p> <ul style="list-style-type: none"> • Method: They first develop a literature study. They implement BIM, carry out evaluations through surveys over several years, and then compare the perceptions of students with different BIM knowledge. • Results: They conclude that the set of motivational activities carried out has not yet had significant effects. The study coincides with the objective of this research (to analyze the development of the BIM implementation and its processes) but it is still immature because it is in the initial stage. It also focuses on BIM training through PBL, superficially exposing the global implementation strategy.
<p>Swallow, Zulu (2019) [49] study the incorporation of BIM 4D in health and safety studies.</p> <ul style="list-style-type: none"> • Method: They adopt a quasi-experimental approach in the form of questionnaires to assess students' perceptions before and after integration into two groups, one using BIM and the other not. • Results: Students in the BIM group demonstrated greater knowledge of both BIM and 4D than those in the non-BIM group. The study highlights the importance of BIM integration in the education of industry professionals but does not analyze integration methods or protocols.
<p>Türkyilmaz (2016) [57] presents the perception of students in an elective course that includes BIM knowledge applied to the design process.</p> <ul style="list-style-type: none"> • Method: The article presents in detail how a course that has been taught since 2007 works. A 10-question questionnaire is created to evaluate students' perceptions. • Results: Despite the benefits shown by the increase in the spatial perception in students, the objective of the study is not assessing methods of integrating BIM into the curriculum or the performance of transversal activities but rather the perceptions of students in a specific course.
<p>Vimonsatit, Htut (2018) [23] present a study where BIM was introduced in two civil engineering subjects and offered as an option to use it in a final year project, taking a more collaborative approach.</p> <ul style="list-style-type: none"> • Method: To analyze the case study, they survey 4th year students. The article explains in detail the objective of each question and the response of the students, including the final open question of the survey in which the students provide comments. • Results: The authors demonstrate the need to incorporate BIM through an exhaustive study of each question in the questionnaire, using the BIM methodology as a learning tool to obtain learning results. The study does not focus on how the methodology should be integrated into the curriculum, but on whether it should be integrated.
<p>Wang, Yan, Fan, Jin, Yang, Kapogiannis (2020) [44] carry out a literature review and propose a project divided into four subgroups with different BIM learning.</p> <ul style="list-style-type: none"> • Method: They explain in detail the tasks of the different subgroups and follow-up with an analysis through surveys. • Results: The study contributes practically and theoretically to the faculty. However, the study is limited to the students' self-perception of the BIM effects according to the subgroup, making a comparison between them. The methods applied for BIM integration are not analyzed, although the authors mention the importance of collecting insights later by tracking their evaluations in the work environment.
<p>Zakharova, Kruglikov, Petunin (2020) [42] describe the competencies that a university should possess through a comprehensive analysis based on the link between BIM and Green Buildings.</p> <ul style="list-style-type: none"> • Method: They conduct an extensive review of the literature on BIM and Green Buildings and propose a tool to evaluate green building by extracting data from BIM models. They describe the approach taken in the performed implementation, highlighting practical methods and collaboration between students and companies. Later, they show the results of the projects. • Results: The students have received awards and certifications for their works, so the results are good. However, the study is aimed at evaluating the results of the Green BIM application rather than on evaluating the processes and development of the implementation itself.
<p>Zhang, Zhao, Wang, Li, Huijser (2020) [45] present a study with the objective of developing an evaluation framework to improve interdisciplinary BIM in roadway engineering education.</p> <ul style="list-style-type: none"> • Method: They first conduct a literature review, where they confirm the importance of interdisciplinary BIM education. They study and compare different evaluation models and decide to use the Context Input Process Product (CIPP) model. They divide the case study into four stages and subsequently evaluate it through interviews and surveys. • Results: Factors were identified to guide educators on how to build BIM curricula. The article presents a possible evaluation framework; it is focused on how to evaluate students and not on evaluating the implementation process.

Table 5. Cont.

Zielinski, Wójtowicz (2019) [51] design a syllabus for a course emphasizing the benefits of using BIM and showing practical examples due to the numerous limitations to the implementation of this methodology in the early stages of university education. They define the initial experience of the students and the limited duration of the university courses as the most prominent limitations.

- **Method:** To carry out the course, they define different levels of BIM maturity and detail at which levels and to what extent it makes sense to integrate them into this course.
- **Results:** The study discusses the design of a course and tries to analyze solutions to the exposed limitations. Other institutions can use this publication to compare the BIM maturity levels of their students; however, it does not analyze the different integration methods, which is the object of this study.

4. Discussion

This study is part of a larger research, which tries to find the optimal way to integrate BIM in a specific curriculum in a university in Spain. As mentioned above, in 2014, the EU-European Directives established the possibility for member states to require the use of specific tools for the electronic modeling of construction data in their procurement process for works, services, and supplies [10,11].

In 2015, pending the transposition of the directives, the then Spanish Ministry of Development (now called the Ministry of Transport, Mobility and Urban Agenda) established the National BIM Strategy, which promoted the creation of an informal forum open to both the public and private sectors (called the BIM Commission or es. BIM initiative) to start working on the dissemination of the methodology [58]. This strategy, among other initiatives, encouraged the establishment of standards, promoted the use of BIM in professional and educational environments, and sought to position Spain as a worldwide reference in the use of BIM.

At the end of 2018, the Council of Ministers approved by Royal Decree 1515/2018 the creation of the Inter-Ministerial Commission for the incorporation of the BIM methodology in public procurement to give new impetus to the BIM implementation process in Spain [59]. The Commission was constituted in April 2019 [58]. From that point on, all national projects of more than 2 million euros and public funding had to be carried out using BIM methodology [60].

In Spain, currently, the incorporation of BIM methodology is included, among others, in the National Reform Program of the Kingdom of Spain 2019; in the Green Public Procurement Plan of the General State Administration, in local agencies, and in the Social Security managing bodies as of February 2019; in the Spanish Circular Economy Strategy of June 2020; and in the “Digital Agenda 2025, an agenda for the digital transformation of Spain”, as of April 2020 [61,62].

Any public procurement must comply with stately, autonomic, or local legislation. Therefore, BIM standards are established by autonomous regions; as a result, the level of BIM implementation in Spain is heterogeneous. However, it is increasingly common to find tender documents aiming for works to be developed using BIM methodology. The weight of such tenders with BIM requirements falls mainly on public infrastructure management companies such as ADIF, AENA, Correos, Puertos del Estado, or Ferrocarrils de la Generalitat Valenciana, which have initiated internal processes of BIM implementation.

As a member of the European Union, Spain must follow its guidelines and is currently obliged to certify all public works in BIM methodology. In addition, there is an increasing exchange of students between countries, so it was important to have an overall view of the processes followed in the world.

In the selected articles, the presence of articles from the US, China, and United Kingdom stands out, although we observed the existence of various publications from around the world. All the studies we covered have been published in different journals/conferences related to technology, education, and construction. Despite these diversities, most articles follow the same pattern, as explained below. Our study demonstrates that the need to assess the implementation of BIM in AEC curricula is scientifically relevant and essential

for effective implementation given the current lack of a clear direction and actions. Taking into account the different strategies, it seems clear that any implementation strategy needs to adapt to the institution, the local government, as well as their needs and rules, and should consider similar published successful strategies.

4.1. Challenges, Advantages, and Disadvantages of BIM Implementation in AEC Curricula

Research demonstrates the effectiveness of using BIM as a teaching tool for design and construction [43,44,50,54]. One of the studies states that students have a high initial interest, which makes the learning experience very effective [23]. For this reason, integrating BIM within the curriculum can create motivated students. It also improves their skills in developing projects and helps them to understand building materials more easily; the visualization helps them to better understand how a building is constructed [44,52,54,55].

Another frequently perceived positive effect of BIM is improved collaboration and communication [48]. Collaborative work is key to experiencing the benefits and challenges of BIM training [38,46,50]. Coordination meetings produce an even greater impact on students than the instructor's performance. Students reinforce the importance of collaborative work in interdisciplinary BIM processes, where it is observed that the better the ability to work as a team is, the better the students' designs and personal experiences will become [45]. There is a direct relationship between the usefulness of BIM for developing course practices and its usefulness for acquiring teamwork skills [31,45,46].

Some of the limitations found in the studies are problems with interoperability between BIM tools and the fact that teachers focus on the use of BIM analysis and creation tools and on collaborative work but not necessarily on information management [47]. As some authors note, the 3D tool could be a barrier to BIM implementation, so it is recommended that teachers emphasize that the 3D tools in themselves are not BIM, thereby turning students' attention to the methodology [46]. Innovative and critical thinking is much more important than mastering software [39].

The obstacles to incorporating BIM into education processes depend on the academic environment, BIM concepts, and BIM tools [55,63]. Most articles highlight these obstacles as common drawbacks across all universities. The academic environment affects the lack of time or credits to incorporate the large amount of technology, motivation, and resources. BIM concepts are affected by a lack of collaboration and teamwork, traditional teaching, and individualized instruction, and by a lack of coordination between institutions. Finally, the teaching of BIM tools is affected by a lack of interest, resulting mainly from a lack of knowledge among teaching staff.

4.2. Processes and Strategies for BIM Implementation in AEC Grades

There is a disparity of opinions about the course in which this integration should be carried out; some authors encourage the inclusion of BIM in the first courses, while others believe that it is more effective to integrate it into the last courses, when the student has more training in the subject.

Regarding implementation strategies or protocols, most of the study cases perform the integration in a project/activity for a specific subject belonging to the area of GE by replacing traditional software with BIM software. However, it is not possible to improve the academic performance of students only by superimposing BIM tools on their thematic content. Therefore, some authors recommend the total redesign of at least one subject [52]. For this reason, some of the studies go further, proposing this same incorporation of technology in graphic expression subjects to be applied later to the remaining study areas. To be able to carry out such an implementation, it must be transversal and, therefore, the collaboration of the remaining subjects is required [26]. This approach leads us to a greater complexity, where the implementation directly or indirectly affects the curriculum as a whole and, therefore, the measures and decisions to be taken are greater.

At this point, some authors propose the design of their own implementation plan or protocol, which they strengthen through the creation or modification of their own academic

guides, rubrics, learning objectives, and so on. Thus, they intend to consolidate their implementation strategy and help both students and teachers throughout the process.

The studies that design their own protocol include a more theoretical proposal in which the approach to implementation is defined in a methodological way covering the entire curriculum and a more practical proposal, as a pilot project, where the content of the different technologies to be included in the different subjects are defined.

4.3. Evaluation Methods

PBL is one of the methodologies most widely used by universities. Therefore, BIM skills training can be offered with an experiential learning approach. Most students appreciate when projects are realistic [44,45].

After BIM integration through PBL projects, many of the studies conduct surveys of students to obtain results regarding their motivation and satisfaction in using BIM methodologies (the results of which have been detailed in the previous section). In other words, they perform BIM integration in a single course and then analyze the results.

However, it should be noted that an implementation in AEC degrees affects the entire curriculum and is a time-consuming process because it affects different courses. There are few studies that evaluate how such an implementation is later applied to the remaining subjects in a transverse manner. Some of these studies go deeper into the methodological aspects, and do not merely focus on the technological application. After applying the case study through PBL, they analyze the data in a more transversal way, not only obtaining the perception of students but also those of teachers, researchers, and even industry professionals. Some of the authors even provide analysis at a more global level, where they try to obtain the result in different academic courses to evaluate the evolution of the said proposal, even making comparisons between different universities. This type of analysis helps them validate the implementation strategy itself rather than the PBL of a specific course.

4.4. Relationship between Industry and BIM Education

As already mentioned, several studies agree on the importance of the interdisciplinarity of BIM educational content. Some authors suggest extending the education to two or more disciplines (interdisciplinary collaboration) or two or more universities at a distance (distance collaboration) to cover skills in coordination, interoperability, and conflict detection [53]. There are proposals for transversal courses involving engineering and architectural disciplines. BIM improves efficiency by facilitating collaboration with other professionals by allowing them to work on the same model in real time [54,56] in both industry and education, so it is essential to take this into account. Therefore, it is fundamental that students understand that professional practice requires multidisciplinary collaboration, especially in a dynamic environment requiring the coordination of different areas of a project.

Many authors state that close collaboration between industry and academia is essential for a two-way exchange between training and reality [37,39,43,45,48,49,52]. The experience of involving professionals from the construction sector with teaching qualifications is key to motivating students and calming their concerns about the needs and expectations of the industry. It is also advisable to involve professionals and stakeholders in case studies to provide advice on how to improve construction with BIM [43]. Close collaboration between employers and educators in the AEC sector will enable the establishment of a stronger joint vision in BIM training [53]. Linking industry and academia will undoubtedly improve traditional teaching [37], this link is also important for some institutions because it is a requirement for accreditation.

4.5. The Need for a Common Implementation Plan between Institutions

As mentioned above, some authors cover BIM implementation in depth in their curricula and develop their own protocols. The realization of such a protocol is highly

complex, and therefore, the authors stress the need for BEP protocols or academic guides on which to rely [47]. These guides are necessary not only for students but also for teachers and educational managers. The authors state that such protocols would support the ability to have sufficient capacity and means to carry out this methodological change in universities. In order to validate their proposal and study improvements, some authors even analyze surveys in different years and/or courses with different versions of the plan design, thus providing a much more in-depth exploration of the implementation's evolution and a validity analysis [40].

Many of the studies highlight the need for coordination between different institutions to provide a basis upon which to build and offer more standardized training, as carried out in industry. In addition, institutions are repeating the same effort instead of taking advantage of the advances made by others, which would allow them to reach a common goal more quickly and efficiently. Authors mention the lack of good practices in the educational field for this type of implementation.

Most of the articles aim to demonstrate the need to implement BIM in the university academic environment but give less importance to how the BIM implementation process should be carried out. The studies mentioned above, which cover how to implement and analyze the implementation process, respond directly and clearly to the objective of this research.

5. Conclusions

The use of ICTs in educational methods is defined in the curricula of many undergraduate and master's degrees, including the architecture degree [64–66]. From an academic viewpoint, these systems are used to improve the acquisition of skills and spatial competences to analyze the visual impact of any building or architectural and urban projects [67–73]. In architectural education, until recently, the use of ICTs was restricted to project implementation processes, where various applications such as Computer Assisted Design (CAD) applications served merely as aids in the execution of one's work, not as tools for the decision making of the architecture and urban planning project [74]. It is true that the new systems as BIM or technologies that model in 3D, such as Augmented and Virtual Reality and even videogames, represent progress to enhance the capacity of spatial and graphic vision and therefore facilitate the process of project conception [75,76]. Although they have the additional advantage of greater motivation in learning and could highly profit from this technology as a method of learning, until now, they have not been considered as tools for architectural design.

It is important to remark at this point that if the use of BIM methodologies is a current and future requirement in the work environment, BIM teaching in universities should be imminent, because tomorrow's professionals are today's students [19]. This approach is a significant part of a wide research project, Game4City 3.0, which is being developed and implemented (2016–2021) in collaboration with two main entities, namely, the Barcelona School of Architecture (Catalonia Polytechnic University, ETSAB-UPC) and the School of Architecture of La Salle—Ramon Llull University (ETSALS-URL), with further collaboration with the Arts and Multimedia Engineering Departments of La Salle-URL. The main activity is limited to the university environment applying BIM, VR, and gamifications strategies to design 3D indoor and outdoor spaces. Nevertheless, the educational proposals are developed, tested, and evaluated considering the local stakeholders' needs and the institutions supporting the project, in order to improve them for further iterations. It is this need for evaluation, and to identify other evaluations of BIM educational approaches, which justifies the need for the systematic review carried out, focusing on the evaluation methods of BIM implementations [77].

Regarding RQ1, the processes and strategies being carried out are different. In the first approach, most centers started the implementation process through a specific subject or activity. Of course, such integration should be designed to favor experiential learning, where knowledge is achieved through practice [38]. However, there is a persistent problem

of integrating this type of technology only in GE. Including it in the graphic department is necessary but insufficient, and integration into the entire curriculum is required [40]: the methodology should be the focus of BIM education, and not the software. Students would benefit more from knowing how to learn and think with a tool than from only knowing how to use it [39]. Some of the articles focus on best practices and case studies through PBL, while others focus on theoretical and reflective analyses. Few perform both in the same study, although the theoretical part is essential to defining the incorporation of this methodology in areas other than graphic expression, where the processes seem more primary than the knowledge of tools [20].

Therefore, teachers should be made aware that this type of implementation does not only affect the graphic expression area. The graphic expression area must lead this type of integration, but everyone involved in the curriculum must cooperate [29]. In addition to teachers, it is necessary to raise awareness of all the people involved in the university, including students, teachers, directors, and even researchers. Indeed, researchers play a fundamental role in this type of intervention: They are not involved in either decision making or scientific analysis to improve pedagogy at the educational level, but they probably have the most knowledge in this field, since these technologies experience constant evolution and research [78]. There is increasing research on BIM implementation in the professional field, but it is still scarce and immature in the educational scientific field. Greater collaboration between different institutions would help this research mature faster and strengthen it. An academic framework perpetually fed by research, discipline, and industry is required to provide effective BIM education [56]. Research and monitoring of the knowledge and skills of students and graduates will better meet their training needs.

Regarding RQ2, most studies carry out PBL projects and analyze their performance through satisfaction surveys. This shows the need to implement BIM in universities, as supported by students and teachers. However, there is no analysis, except in some specific cases, of the feasibility of such a method or of the implementation strategies carried out.

BIM should be introduced into the curricula not only to respond to the demands of the industry but also to facilitate learning, because it supports the understanding of content [44,47–50,52]. The directors of educational faculties have regular meetings in which they seek to ensure that the curricula provide the appropriate competencies. The BIM methodology should not affect competency acquisition; in fact, it should help to achieve them. BIM is not intended to change the content or the objective of the curricula but rather the methodology with which they are carried out.

In the professional field, due to industry requirements, there are guidelines and standards for the realization of BIM implementation. However, this is not the case in academia. This leads us to RQ3: Does an academic BIM implementation guide exist or is one being researched for use as a reference for educational centers? Apparently not. However, the systematic review shows that schools are asking for such a guide.

Universities face great challenges in successfully implementing BIM courses in curricula [54]. They have common problems in implementing BIM in their curricula, yet they make disparate proposals for solutions. An action protocol, guide, or standard for all institutions would simplify the process and provide them with more confidence in carrying out such an implementation. All the articles analyzed conduct individual studies, but there is no standard upon which to base them. Universities implementing such a methodology should also follow standards to improve coordination, collaboration, and the effectiveness of this type of implementation. There are several examples that could serve as a guide for various institutions. It is necessary that the people implementing BIM in a university have a protocol to rely on, supported by coherent and common principles, and based on improving the acquisition of student competencies through BIM methodologies. Some institutions have engaged in collaborations and comparisons with others, and they demonstrate the importance of institutional collaboration to reduce effort, share benefits, and refine processes [37]. Such cooperation would be a step forward to prevent errors and would help other centers integrate these methodologies and avoid unnecessary work.

This study may be limited, as are other systematic reviews of this type, by the specific search keywords and the bibliographic databases chosen. Other keywords and/or other places of publication would likely yield somewhat different content.

To complete this study and, as a future line of research, a reflection on coordination between institutions is necessary to provide universities with the necessary standards so that they, individually, can strengthen transversally between subjects when carrying out BIM implementation in their curricula. Therefore, it is necessary to develop scientific literature in which researchers from different faculties can cooperate in search of common solutions.

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