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Bim Education. A Qualitative Discussion From A Bibliometric Analysis.

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Abstract.

The applications of the Building Information Modeling (BIM) methodology in the educational field have become more recurrent in the publications of recent years, resulting from the neediness of the AEC Industry (Architecture, Engineering, and Construction) to absorb qualified professionals prepared to realize the skills that the methodology requires. This reality generates, therefore, new demands for Universities.

Based on this new dynamic and using the VOS viewer software, this research performed a bibliometric analysis exposing the knowledge network on the subject of BIM Education. As a process, some maps are created representing the central themes most addressed by experts, the groups of authors and their relationships, as well as data on the dynamics through time. The bibliometric analysis also allowed the extraction of data on the most critical documents related to the theme.

This research aimed to qualitatively examine the data collected by bibliometric analysis in the field of essential documents for BIM Education and discuss the teaching trends of BIM methodology, identifying the primary approaches, and suggesting ways for the formulation of academic modules based on the current literature.

Keywords: BIM Education, VOSViewer, Bibliometric Analysis, BIM teaching

Introduction

Analyzing the BIM methodology implementation barriers in the AEC market is a way to understand where the process is most fragile and thus plan more assertive investments. In this context, this complexity is the issue related to the training of professionals for the new skills needed, which are crucial for the success of the project(Walasek & Barszcz, 2017).

BIM Education is addressed as an obstacle from various perspectives, such as industry, valuing the need for government support to develop standards, invest in technological innovation of professionals and encourage the process of knowledge transfer (Run-Run Dong & Martin, 2017). From the perspective of convenience in producing research in favor of a BIM curriculum that is not focused only on specific software issues, it also helps train professionals ready to perform functions in the industry such as BIM management and collaborative work (Smith, 2014). Following the same argumentative line, BIM education, which also translates as training, is pointed out as responsible for 59% of the opinions on implementation barriers in the United Kingdom, a reference country in encouraging the

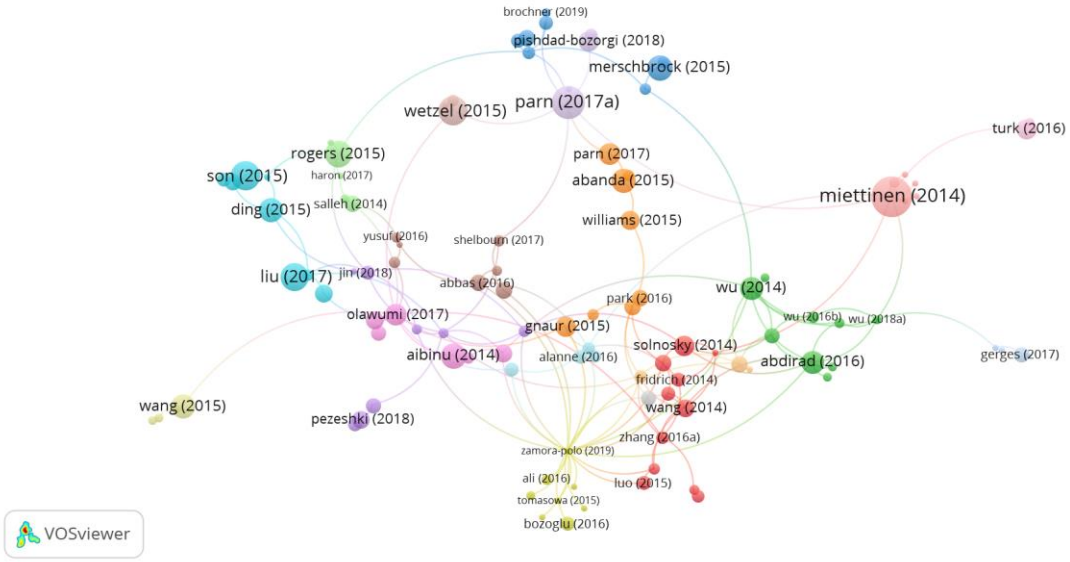
implementation of the BIM methodology (NBS, 2019, p. 22), which confirms the need for investment in this field.
From these circumstances, some studies focused on the development of the topic stand out, aimed at creating a theoretical foundation for research in the area, such as investigations on Education in the construction field, where arguments emerge about the inevitability of identifying the best teaching practices and in directing BIM teaching since 2006. On this occasion, it was already highlighted as challenges and indications of the need to deepen in subjects such as BIM curriculum and results from evaluation criteria (Zheng et al., 2019). BIM Education is highlighted in a bibliographic review in the study by Santos (Santos et al., 2017), which places the topic as a subcategory of a group of main themes on BIM, exposing, among other issues, a need to implement practical projects capable of combating the inconsistency between academic production and real problems of site and management. Similar results appear in 2017 (Olawumi et al., 2017), demonstrating some specific aspects of the theme with the division into subthemes that would be linked to the need to deepen BIM education.(Zheng et al., 2019)(Zheng et al., 2019)(Santos et al., 2017)(Santos et al., 2017)(Olawumi et al., 2017)(Olawumi et al., 2017)

1.1 Method: Bibliometric analysis

Based on this conjuncture, this research starts from a bibliometric analysis, a method capable of monitoring and analyzing the knowledge structure of science (Thomsom Reuters, 2008), and which allows the author to orient himself in the face of the complex panorama of the field to be investigated (Zupic & Čater, 2015)
The quantitative analysis of bibliometric results can be interpreted as an indicator that it is a relevant topic in the face of significant importance given by researchers. Therefore, the reference to the subject is scientifically useful. (Garfield, 1979). From this and using VOSviewer, maps can be created, and they represent the interconnection of the known elements of the system. To find and illustrate the relationships between research subjects that may be distant, but genealogically link is a beneficial method for the development of scientific research (Holton et al., 1996)
This research performed data about BIM Education theme, the main issue of this investigation is to find the network of documents that make up the data set on this subject. The results from VOSviewer are the structure of the more correlated material in some groups of interest. These groups were analyzed qualitatively intending to understand the critical topics and direct the discourse to new BIM teaching organizations.
The data selection started from parameter uses in VOS Viewer: "citation," "documents," minimum documents, and citation(one) and adding the relationship filter. This means that only documents that relate to each other were considered. This filter generated a sample space with 111 documents that make up the BIM education subject structure to be evaluated (Figure 1).
The result generated by VOSviewer considers the relationships between documents, divided them into 19 clusters of relationships. These groups were analyzed qualitatively to find a

pattern that identifies the main paths of interest of experts and points to a direction for a future deepening of a BIM curriculum in universities.

Figure 1- BIM Education document map



2. Qualitative analysis of results:

2.1 BIM Education from the teaching perspective methods, student's perception, life cycle, and teaching modules

As a starting point, the observation is that there is already a vast interest in deepening the literature on BIM education. The forms of approach are quite diverse, which is what shows the division into groups.

For group 1, we observe the framing of documents in an approach on BIM teaching methods in different situations, such as in case studies on the need to include BIM as a project coordination tool(Fridrich & Kubečka, 2014) demonstrating to students in practice the process changes that the use of BIM tools provides. Still, on processes, methods of teaching collaboration between teams is an explored theme (T.-H. Wu et al., 2019) and in ways of demonstrating to students the possibilities of virtual cooperation through the implementation of collaborative platforms and the development of virtual reality communication.

The creation of metrics for evaluating new disciplines and developing students on the tools is also a focus, demonstrated during the production of teaching modules that use sustainability tools. These tools are included in educational programs through practical classes with the interaction between students (Luo & Wu, 2015) Therefore the creation of teaching modules focused on BIM tools is a practice and a fundamental approach to finding what they are real student's learning needs. To this end, investigations with industry input appear in this group of

methods(Zhang, Schmidt, et al., 2016) they create teaching modules based on the real priorities of a curriculum that will meet the construction market soon.

Group 2 identifies research methods that approach Education to assess participants' perception, that is, of the students or professionals involved. This category presents the students' view on the implementation of a curricular module(Maina, 2018) identifying barriers and advantages; evaluation of students' perception in practical modules with software in curriculum integrated to the curriculum, or extracurricular (Hu, 2019).

In addition to the pedagogical theme, the selected documents also create a theoretical structure based on participatory methods, such as Focousgroup, surveys, and Delphi Method for the research metric. In this case, there is the identification of the need to create a teaching framework, which means a set of validated information to unify BIM concepts identifying the skills necessary for the execution of BIM activities in a multidimensional manner (W. Wu et al., 2018a, 2018b) These skills need to be explored in the context of complementary disciplines, such as facilities projects (MEP), making it necessary to deepen pedagogical techniques that develop students' skills relating to MEP, costs, and management(Zhang et al., 2018)

The results of the case studies are essential to understand the BIM maturity, and one concern is to develop it according to real cases of construction. For such one possibility is to work it from the "project-based learning" method with the industry participation and the creation of an evaluation metrics. Another way is to create a "framework" that establishes a link between the growth of what was proposed to the project quality works and the time required to achieve the results(W. Wu & Luo, 2016)

Group 3 focuses on issues related to the dissemination of collaboration to meet the project life cycle. This dissemination addresses topics about case studies on collaborative work in the industry(Merschbrock & Munkvold, 2015), correlating this to the theory of the diffusion of innovation(E. M. Rogers, 2003). Collaboration is one of the BIM processes and, as such, for its full use in projects is necessary to be taught, trained, and is this perspective of this group of documents.

The subject is also addressed from the perspective of retrofit projects focused on sustainability(Bu et al., 2015) or research on MEP projects that use BIM coordination tools such as clash Detection, which, from this perspective, presupposes the collaborative process to work. In addition to an example of collaboration and coordination in the operational phase (Brochner et al., 2019) namely the "Facilities management" processes.

For the operational phase, the maintenance management processes are discussed to complete the cycle of a project. The literature is presented in an organized way to identify the approaches still lacking in the industry (Roberts et al., 2018) identifying the main themes such as inaccuracy and interoperability of data, intellectual and virtual property of projects to be used in the operation phase, training and most important requirements. Not least, case studies are addressed to demonstrate external (governmental) internal (project experience) influences that interfere in the maintenance of the constructed assets and the relevant information to be inserted in the models (Lindkvist, 2015)

Group 4 is related to the theme of creating specific teaching modules for BIM, or as already exposed, in the form of a framework that gathers the information to be taught in an organized manner. The sample of this group recognizes the contribution of the existing literature that addresses case studies but adds the need to change the academic curriculum considering the

new BIM tools and particularities. This need is demonstrated through suggestions of modules that fall into the existing academic curriculum(Hjelseth, 2015a; Rodriguez-Rodriguez & Davila-Perez, 2016), on resumes that focus on building a bridge with industry through collaboration (Bozoglu, 2016; Snyder, 2015) or in investment in specific topics as to improve the perception of material extraction, costs, and planning, themes that arise both in pre-construction and in post-construction(Ali et al., 2016)
Among these topics, we observe the inclusion of teaching methods such as "project-based learning," combined with "blended learning" in the teaching of BIM cost estimation (Y.-W. Wu et al., 2016) as a strategy for organizing a new teaching module. The modules are exposed in the format of case studies, and the importance of evaluating students on this learning is also discussed (Tomasowa, 2015)

2.2 Case studies as validation, BIM atmosphere, interaction and status assessment in BIM education

Although the evaluation method by case studies of BIM application in Universities is not a singularity, the presence of this type of analysis appears as an essential and relevant point in group 5. In this group, are validated research in classrooms is showed as a BIM framework for teaching structural design. The approach valuing not only the accurate vision of the professional when he develops a project (Nawari, 2015) but are also exposed examples of the ongoing implementation of engineering and architecture from an overview of the curricular structure and the framework of BIM concerning the other disciplines of the curriculum (R. L. Solnosky & Parfitt, 2015).
These relationships are observed and applied more punctually through the project case studies, for example, of sustainability with the creation of study modules focused on the use of specific tools such as Revit Energy Modeling (Lewis et al., 2015) or in applications of information technology for a sensor network in energy efficiency projects (W. Wu et al., 2015).
Other topics validated by application in universities expose BIM teaching frameworks in structural engineering from the perspective of the professional responsibility, not only with the discipline of structure but in collaboration with other areas (Nawari, 2015). The test evaluations are also present in this group, demonstrating the students' perception of the BIM implementation (Zou et al., 2019)and the requirement for structure, applying, and understanding how the implementation was absorbed.
Group 6 is represented by references exploring the theme of the BIM atmosphere in engineering or architecture organizations (Ngowtanasuwan & Hadikusumo, 2017), showing the structuring through a case study, such as in the institutional area. This latter, focusing on the understanding of the entire production chain where BIM is inserted (Papadonikolaki et al., 2017) and the production of parameters that can be used to evaluate BIM culture on a large scale—in this case, exemplified with the case study between two Chinese cities already inserted in the BIM production chain but with distinct characteristics (Xu et al., 2018)
The cities were evaluated from the perspective of perceptions about BIM culture and atmosphere, aiming to create large-scale documentation for the country. The organizational area is shown through an example of an architecture company that evaluates the implementation on a full scale and observes critical factors such as management support,

subjective norms, competence in new software (Ding et al., 2015; Son et al., 2015). The methodology use perception is directly linked to BIM education along the border between success or failure, depending on the degree of knowledge of the professionals involved. In an illustration of this statement, we have the exposition of cases that discuss the incentive to internal training in companies (Ahn et al., 2016), exposing implementation strategies focused on professional training and internal evaluation. Also, on assessments, we note the interest in investigating the necessary competencies of professionals(Y. Liu et al., 2017) which means the areas of knowledge or concepts to work on for the development of BIM implementation.
About group 7, there is a predominance in the model interaction approach with the user. It is exposed thought the perspective of augmented reality (Williams et al., 2014), virtual reality exemplified as a teaching module for civil construction, where expose that almost half of BIM related publications are about model visualization tools that help the user understand the project, showing the advantages and disadvantages of the application (P. Wang et al., 2018)
As in the other classifications, the subject appears in different perspectives, such as using an energy performance case study (Patino-Cambeiro et al., 2017) and the use of tools such as plugins for the operational phase in facility management field(Pärn & Edwards, 2017) The pedagogical area is approached from the perspective of the use of virtual reality increasing the interaction with the student to organize a teaching module in which there is participation from the object model, going through the phase of implementation of the prototype until its evaluation(Park et al., 2016)
Group 8 shows an approach to reports on the status of BIM implementation in universities. Case studies with surveys applied to students to evaluate the change in the system are used (Yusuf et al., 2016), exposing data on the inclusion of BIM in American Universities as a reference source for application in other locations, in this case, Pakistan (Abbas et al., 2016).

2.3 BIM professional approach, business model maturity and BIM implementation in Education

In group 9, investigations focused on the professional and BIM state-of-the-art. The sample shows a bibliometric analysis using methods, selection criteria, and defined objectives (Olawumi et al., 2017), resulting in the identification of BIM categories of subjects highlighted.
The lens about the BIM professional is developed through research with the industry, aiming to identify competencies, personal characteristics, professionals, knowledge, and skills that a BIM professional should have and expectations regarding Education in this area(Bosch-Sijtsema et al., 2019). Another situation that shows the professional bias is a Finnish investigation comparing job offers made available online with the official information of a job platform (Uhm et al., 2017), contributing to a less generic identification of the BIM professional positions.
The BIM market perspective is in practice in group 10, highlighting the need to include the market perspective to evaluate the evolution of BIM implementation. As an example, there is another Finnish research about the most significant BIM organizations opinion that is representing this market, evaluated after 2007, which is the year of the beginning of the BIM requirement for public works (Aksenova et al., 2019), highlighting the need for investment in

changing the "business model," which means the BIM work model. The market also appears to evaluate the maturity of implementation(Siebelink et al., 2018) by creating a model applied in organizations and placing Education as a criterion to rate the implementation.
The implementation is highlighted in group 11, through the exposure of industry case study data, for example, a Nigerian that shows results as critical factors for implementation (Amuda-Yusuf, 2018) the assessment of maturity from the companies perspective through a focus group, collecting data to understand the real situation in Malaysia (J. Rogers et al., 2015).

2.4 Design, security and facility management practices as topics of interest in BIM Education

The massive project's explanation sets the Grup 12, interpreted from the education perspective as examples of project practice. It presents publications that demonstrate the results of interviews about airport projects (Ozan Koseoglu et al., 2019), the challenges and barriers in the use of BIM from project to execution. Another point is the combination of management techniques such as Lean Construction and BIM, also demonstrated in a case study project(O Koseoglu et al., 2018)
The theme of group 13 stands out around safety stands, the use of BIM and its visualization tools assisting new design techniques (Vandecasteele et al., 2017)
At this point, the group categorization into themes are related to the specific type of project, and group 14 is one of the examples in which the theme facility management stands out. A bibliographic review is presented (Parn et al., 2017), exposing state of the art and Education is addressed from the perspective of the BIM implementation barrier of this theme. In this context, lessons learned are presented through case studies and give an overview of the processes execution for a good result from obtaining the data through the transfer until its use(Pishdad-Bozorgi et al., 2018) Another example is the concern of investment in the operation of the building already in use is exposed by the use of BIM combined with laser scanning tools aiming to create a scanning method applied to the recognition of internal furniture (Stojanovic et al., 2018)

2.5 Organizational change, student evolution, operational, technical approach, barriers, and challenges, management

The organization change discussion with the BIM implementation sets Group 15. The theme is addressed from various perspectives as in the rate of the BIM implementation at organizations, discussing productivity with the use of information technology (Lindblad & Vass, 2015)
In addition to treating directly through the lens of Education through case studies that assess the abilities of students before and after BIM learning (Lopez-Zaldivar et al., 2017), indicating as results some levels of students knowledge. The changes are also exposed through the student's production, the interest of the themes of master's and doctoral oriented theses. This change demonstrates the development of BIM in the University and establishes guidelines to ensure the progress of projects in this new teaching organization.

The concern about the evolution of the student is put on the agenda in group 16. It is explored through experience with monitoring four semesters, with a specific BIM teaching module and defined project (W. Wu & Hyatt, 2016). Another demonstration is the experience of collaboration analysis (Bellido-Montesinos et al., 2019), where the evolution of the teams, the flow of information between the disciplines were evaluated.
Group 17 could be linked to group 14, but a more pragmatic approach is noted. The vision placed here is the need to create processes for the operational phase information such as the collection of data for the creation of a framework that contains the attributes to be included in the case of a security project (Eric M Wetzel & Thabet, 2015) or the definition of these for assistance in maintenance and operation of the constructed asset. In addition to the information structure, it is necessary to ensure the transfer of these to the next phase, and then, the interoperability of software and processes is a relevant subject (E M Wetzel et al., 2018). Not far, developing technologies that aim at automating processes is also exposed(Lu et al., 2018) as in the use of image recognition tools in the operation phase, organize and store automatically.
BIM generalities set group 18, a series of references on BIM barriers and challenges exposed on government issues such as in the case of BIM implementation research aimed to identify the government duties about this (Run-Run Dong & Martin, 2017) in addition to the mention of quality management and talent training (R.-R. Dong, 2017) also absorbing generic BIM information formats that encompass diverse topics(Turk, 2016).
The last characterization is group 19, the smallest of them, with only two documents that will be analyzed from the management perspective. This theme is identified in collaborative platforms' use to evaluate work deliveries during three years of University course (Comiskey et al., 2017). The platforms were tested to evaluate the information exchange in the project, a process that is part of the model information management. The lessons learned in the BIM teaching module implementation in construction management courses focused on the life cycle development of the projects executed through BIM methodology. It considers phases such as definitions, workflow, cost estimation, planning simulation, incompatibilities analysis, communication evaluation(Leite, 2016).

3. Discussion

The qualitative data analysis and the division by groups open several paths for discussions on the BIM Education theme. The group division allowed a deepening of some issues and directed the reasoning of the interpretation in some main points.
It is a reality the need for a structured reorganization of teaching in courses related to civil construction. Based on this argument, the analyzed literature recorder some forms of organization, such as the tendency to consider student participation. It should be done through a closer approach between the parties so that there is enough information to understand the real difficulties of learning the methodology. Added to this is the integration of new disciplines with traditional ones since the courses have many other skills and contents that are significant.

The teaching modules with collaborative projects have significant importance in this theme. For better use is indicated the participation of industry in real case studies, with learning requirements based on difficulties drawn from market problems. This continuous flow of collaboration is beneficial for the development of the BIM method, in the sense that the industry produces the requirements but is not able to provide the knowledge. It needs to be worked on in an organized manner, including content on project and information management.

Table 1- BIM Education Groups

Cluster	Documentos	Grupos
1	(Adamu & Thorpe, 2016; Blanco Caballero et al., 2017; Hammi & Bouras, 2018; R. Solnosky et al., 2015; L. Wang & Leite, 2014; T.-H. Wu et al., 2019; Zhang, Schmidt, et al., 2016)	Teaching Methods
2	(Hu, 2019; Luo & Wu, 2015; Maina, 2018; W. Wu et al., 2018a, 2018b; W. Wu & Issa, 2014; Zhang et al., 2017, 2018)	Students' perception
3	(Brochner et al., 2019; Bu et al., 2015; Fridrich & Kubečka, 2014; Lindkvist, 2015; C. Liu et al., 2017; Merschbrock & Munkvold, 2015; Paern et al., 2018; Rahman et al., 2016; Roberts et al., 2018)	Life cycle
4	(Ali et al., 2016; Bozoglu, 2016; Hjelseth, 2015b; Rodriguez-Rodriguez & Davila-Perez, 2016; Tomasowa, 2015; Zamora-Polo et al., 2019)	Teaching modules
5	(Amuda-Yusuf & Mohamed, 2015; Jin et al., 2018; Lewis et al., 2015; Nawari, 2015; Pezeshki & Ivari, 2018; R. L. Solnosky & Parfitt, 2015; W. Wu et al., 2015; Zou et al., 2019)	Validation by a case studies
6	(Ding et al., 2015; Han et al., 2016; Y. Liu et al., 2017; Matthews et al., 2018; Ngowtanasuwan & Hadikusumo, 2017; Papadonikolaki et al., 2017; Son et al., 2015; Xu et al., 2018)	BIM atmosphere
7	(Abanda et al., 2015; Gnaur et al., 2015; Park et al., 2016; Pärn & Edwards, 2017; Patino-Cambeiro et al., 2017; P. Wang et al., 2018; Williams et al., 2015; Zhang, Xie, et al., 2016)	Interaction

8	(Abbas et al., 2016; Babatunde et al., 2018; Kovacic et al., 2015; Puolitaival & Forsythe, 2016; Shelbourn et al., 2017; Sonja Kolarić, Mladen Vukomanović, Dina Stober, 2017; Yusuf et al., 2016)	Assessment/current status
9	(Aibinu & Venkatesh, 2014; Bosch-Sijtsema et al., 2019; Gilkinson et al., 2015; Lee et al., 2015; Olawumi et al., 2017; Uhm et al., 2017)	BIM Professional
10	(Ahankoob et al., 2018; Aksenova et al., 2019; Miettinen & Paavola, 2014; Saridaki et al., 2019; Siebelink et al., 2018)	Business maturity
11	(Amuda-Yusuf, 2018; Ferrandiz et al., 2018; Haron et al., 2017; J. Rogers et al., 2015; Salleh & Fung, 2014)	Implementation
12	(O Koseoglu et al., 2018; Ozan Koseoglu et al., 2019; Nasila & Cloete, 2018)	Design Practice
13	(Hong & Lee, 2018; Vandecasteele et al., 2017; S.-H. Wang et al., 2015; C. Wu et al., 2015)	Specific projects
14	(Parn et al., 2017; Pishdad-Bozorgi et al., 2018; Stojanovic et al., 2018; Thabet et al., 2016)	Facility Management
15	(Alanne, 2016; Lindblad & Vass, 2015; Lopez-Zaldivar et al., 2017)	Organizational change
16	(Bellido-Montesinos et al., 2019; Lucas, 2017; W. Wu & Hyatt, 2016)	Student Progress
17	(Lu et al., 2018; E M Wetzel et al., 2018; Eric M. Wetzel & Thabet, 2015)	FM Framework
18	(R.-R. Dong, 2017; Run-Run Dong & Martin, 2017)	Barriers and challenges
19	(Comiskey et al., 2017; Leite, 2016)	Management

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